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THE INSTITUTE OF PHYSICS

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The Internal Constitution of the Earth and Planets

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[The Einstein Memorial Lecture, sponsored by the South Australian Division of the Institute's Australian Branch and given in Adelaide on October 1, 1959]

I SHOULD first like to thank The Institute of Physics for the honour it has done me in inviting me to give the 1959 Einstein Memorial Lecture before this large audience. I had the good fortune to meet Einstein twice. The first occasion was a brief introduction in Cambridge in 1932. The second was in 1954, a year before his death, when he granted me the privilege of an hour's interview in Princeton. To my surprise he talked to me during that hour, not on Relativity, as I had expected, but on the structure of the Earth, and in fact on some of the topics I shall be mentioning in this Lecture.

My subject to-night is concerned with the planets of our solar system. The planets are divided broadly into two groups. The first group consists of the " terrestrial " or " inner " planets, which have sizes and densities not too different from those of the Earth. In order of increasing distance from the Sun, they are: Mercury, Venus, the Earth and Mars. The second group consists of the " major " or " outer " planets—Jupiter, Saturn, Uranus and Neptune—which are all much larger and at the same time appreciably less dense than the Earth. There is also the planet Pluto, not discovered till 1930, further out than Neptune, but comparable in size with the Earth. In addition, I shall be mentioning our Moon, much larger compared with its planet than any other satellite of the solar system, and for some purposes classed as an inner planet.

It is about the interiors of planets that I shall be talking. I shall naturally have by far the most to say about the planet Earth, since this happens to be the one which man inhabits (just at the moment at any rate) and the one on which he at present gathers all his observations. Later on, I shall venture comments on the interiors of all the other planets except Pluto, about whom we know very little as yet.

It may seem bold to purport to know anything about the deep interior of even the Earth, let alone other planets. The deepest mines penetrate less than two miles below the surface, and the deepest boreholes not so much further. These are the merest pinpricks in an Earth of radius 4,000 miles, and, moreover, have been made in only a few places. So we know very little about the Earth's interior by direct observation. But, as I hope to show, there is much clear evidence from other sources.

A vital early step was Newton's work on gravitation which yielded comparisons of the mass of the Sun and various planets. The work showed quite early that the mean density, or mass per unit volume, of the Earth is about 4 times that of the Sun and of Jupiter, about 1·1 times that of Venus, and so on.

These figures of course give only the comparative densities of planets. But it is remarkable that Newton made a very plausible guess that, to quote his words, " the quantity of whole matter in the Earth may be five or six times greater than if it consisted all of water." Further, Newton pointed the way to determining the actual mass of the Earth by suggesting measurements of the deflection of a plumb-line suspended at the side of a mountain. The idea was that the deflection would give the ratio of the sideways gravitational pull of the mountain to the downward pull of the rest of the Earth. Provided the mass of the mountain could be estimated, it would be possible to deduce the absolute mass of the Earth, and thence the masses of the Sun and other planets.

The first experiment on these lines was carried out in 1738 by Pierre Bouguer on the 20,000 feet Peruvian mountain Chimborazo, the mass of which was estimated from surveying data and measurements of densities of rock samples. The results were good enough to refute

theories, current at the time, that the Earth is a hollow shell, or a globe full of water, but they fell short of yielding a close estimate of the Earth's mass.

A similar, but more accurate, experiment was carried out in 1776 on Mt. Shiehallion in Scotland by Neville Maskelyne, and gave for the mean density of the Earth the figure of 4½, later raised to 5 when the mass of the mountain became better determined. By "density" of 5, I mean a density five times that of water, and this meaning will apply to all the density values I give tonight.

A different method of finding the Earth's mean density was devised by John Michell, who constructed apparatus to measure the mutual attraction of relatively small bodies inside the laboratory. Such measurements, combined with the known value of the acceleration of a body falling near the Earth, can also yield the Earth's mass. In 1798, Henry Cavendish used Michell's apparatus to obtain a value near 5½ for the Earth's mean density, a famous result which more recent work shows to be accurate to one part in 300.

Now the mean density of rocks for some miles below the Earth's surface is known to be less than 3. It is also known that, with very minor exceptions, the density must increase downwards towards the centre of the Earth; for in the course of the thousands of millions of years of the Earth's lifetime, gravity would see to it that denser materials were in the main transported to levels below lighter materials. The Cavendish result thus made it clear that most of the Earth, and especially the deeper interior, must consist of material at least nearly twice as dense as surface rocks.

But we are still a long way from knowing how the density varies in detail inside the Earth. Consider for example two solid spherical balls, which I will call *A* and *B*, of the same size and outward appearance. Suppose that *A* has a uniform density 5½ throughout, while *B* consists of an outer layer of density 4½ reaching half-way to the centre, and enclosing a core of density 12½. A little arithmetic shows that both balls have the same mass and mean density, in spite of the wide difference in their internal constitutions.

We can, however, devise a simple experiment to tell which is which. All we have to do is to roll them down an inclined plane and observe the times taken. The ball *B*, the one with the dense core, will be found to roll the faster, taking in fact 3½ per cent less time for the same distance.

If we start from this last result as observational data, we can calculate from dynamical theory that the "moment of inertia" of the ball *B* is only about five-sixths that of the uniform ball *A*. Moment of inertia is a property of a body connected with the degree of central concentration of its mass. The smaller the moment of inertia, the greater the central concentration, and the more readily can the body be made to spin or roll. The experiment thus verifies that the ball *B* is denser near the centre than *A*.

We can likewise use dynamical theory to throw light on the degree of central concentration of mass in a planet, though this won't be quite a simple matter of rolling the planet down an inclined plane.

What is done in the case of the Earth is to apply dynamical theory to observations of the Earth-Moon system. The Moon's attraction on the Earth's equatorial bulge causes the direction of the Earth's axis of spin to change periodically. The changes are revealed in astronomical observations, and in conjunction with data on the Earth's spheroidal shape, enable us to deduce that the moment of inertia of the Earth is nearly five-sixths of the value that would be yielded if the density were constant throughout the interior.

It follows that the structure of the Earth is closer to that of the ball *B*, the one with the dense core, than to the uniform ball *A*, and that the density near the centre must in fact be quite substantially greater than 5½.

In a similar way, though with more uncertainty, we can learn a little about the distribution of matter in other planets, for we know their mean densities fairly well, and also have values of the moments of inertia in several cases. I shall keep to the Earth, however, for the moment.

It is essential that any picture of the Earth's interior must agree with the known values of the mass, volume and moment of inertia. But there are many possible distributions of mass compatible with these values, so that we are still a long way from knowing the full picture, and need more evidence. As it happens, the Earth herself provides what is basically wanted in the form of earthquakes, and in fact provides lavishly.

In an average year, there are ten earthquakes which are national disasters. Another hundred are classed as destructive earthquakes, while a thousand do at least some damage. Ten thousand others are strong enough to cause alarm, and one hundred thousand are felt by human beings. In addition to that, many earthquakes not felt are recorded on delicate instruments called seismographs.

The energy released in the largest earthquake is about a thousand million times that in the smallest felt earthquake. In the extreme earthquake, the energy is about the same as the total energy in a major hurricane, with this difference that, whereas a hurricane takes some hours or more to spend itself and covers a wide area, the energy in an earthquake issues in the space of a few seconds at most from a confined focal region below the Earth's surface. The energy in the extreme earthquake is nearly a hundred thousand times that in the larger atom-bomb explosions and even dwarfs hydrogen-bomb explosions.

It was the same John Michell, who devised the apparatus from which the Earth's mass was first accurately estimated, who first saw that energy is sent out from an earthquake focus in the form of earthquake or "seismic" waves. Many earthquakes every year are strong enough to send waves to the nethermost regions, and the waves rise again to be recorded all over the Earth's surface on seismographs. A sizable earthquake in say the North Atlantic region will result in your Adelaide seismograph recording, some twenty minutes later, seismic waves that have passed right through the centre of the Earth.

The records or "seismograms" thus traced in the world's thousand or so observatories from countless earthquakes provide the basic observational data from

which the seismologist works. It is his task to decipher the records—to work back from them to detect the source characteristics of earthquakes, and the features of the Earth's interior which modify the waves in transit.

In this task, he is, in effect, X-raying the Earth. Some features he sees only " through a glass darkly " so to speak; others he discerns with great clarity. He is for example as sure that the Earth has a large well-defined core as that it has a Moon. Both objects, Moon and core, are revealed through wave transmission, in the one case optical and in the other seismic, but both equally certain means.

A necessary step in X-raying the Earth is to set up a reliable theory of the transmission of seismic waves. The waves are of the nature of mechanical vibrations, and involve to-and-fro motion of particles inside the Earth as they pass by. The wave motion occurs because the internal materials of the Earth are deformable or elastic; and a first requirement is to represent the elasticity of the Earth suitably.

Here, the seismologist has to face an important question of scientific method. He knows from laboratory experiments that the deformation of many ordinary solids and fluids (though by no means all) can be represented by the relatively simple mathematical equations of perfect elasticity. An essential feature of perfect elasticity is that the equations for a particular material contain just two coefficients, representing the " incompressibility " or " bulk-modulus," and the " rigidity." The incompressibility specifies the material's resistance to change of volume under symmetrical pressure, the rigidity to distortion of shape. In ordinary circumstances, a " solid " has considerable incompressibility and rigidity, while in a " fluid " the rigidity is negligible compared with the incompressibility; thus a fluid readily changes its shape to fit a containing vessel.

It does not follow automatically that this simple representation will suffice for the Earth's interior where pressures are abnormally high. What the seismologist does is to use the equations of perfect elasticity as a trial hypothesis. He knows of course that mathematical equations have no status in natural philosophy except to the extent that they represent the observations—in this case the data gleaned from seismograms—adequately for the purpose in hand. He is therefore at pains to carry out necessary checks against the data, and he finds that the theory of perfect elasticity does in fact lead to a suitable description of the main seismic observations. In particular, the theory is adequate for all the inferences I shall be making to-night.

It follows that the terms " solid " and " fluid " can be validly used in relation to the Earth's deep interior, provided the meanings are made clear. The meanings are in terms the values, large or small, of the coefficients which correspond to incompressibility and rigidity in the mathematical equations; they relate to the elastic behaviour of the Earth under stresses which change fairly rapidly, as in seismic wave transmission. The only difference from simple practice is that, whereas the two coefficients for an ordinary substance are derived by matching the equations against fairly direct laboratory measurements, they are determined for the Earth's interior by matching against seismic and related data.

If I appear to have laboured this point, there are several reasons. First, it is desirable that I should give you a glimpse of the type of thinking the explorer of planetary interiors brings to bear in his scientific method. Secondly, the use of terms like " solid " and " fluid " can be highly misleading if explanations are not given: there exist contexts in which two coefficients do not give an adequate description of the Earth's deformability. Thirdly, the incompressibility and rigidity happen to be two of the most important items involved in unravelling the Earth's internal physical structure.

The next step is the deduction from the theory that three broad types of seismic waves are possible.

One type consists of waves (the Rayleigh and Love types) which travel over the Earth's surface and do not penetrate to great depths. These waves throw valuable light on the structure of the outermost 25 miles or so of the Earth.

The other two types, called bodily waves, penetrate downwards and supply information on the deeper interior. They are the " primary " or *P* waves, and the " secondary " or *S* waves, respectively, both of which travel faster than surface waves, and contribute to the earlier part of the record on seismograms. The *P* waves are longitudinal, like waves in sound, while the *S* waves cause particles to move sideways to the direction of wave advance. In solid materials, the *P* waves travel about 1¾ times as fast as *S* waves, while *S* waves, which depend crucially on the rigidity, do not pass through fluids. Thus detection of both *P* and *S* waves in a part of the Earth is immediate positive evidence of solidity. Likewise, failure to detect *S* waves is negative evidence of fluidity. In rocks near the surface of the Earth, *P* waves travel at a speed of about 3 miles per second, *S* waves at about 2 miles per second. In the oceans, *P* waves travel at about a mile a second. The greatest speed of *P* waves in the Earth is about 8½ miles per second, and is reached 1,800 miles below the surface.

P and *S* waves were first identified on seismograms by the Englishman R. D. Oldham in 1897, some seventy years after the theory of elastic bodily waves had been worked out. Oldham's work provided an early check on the relevance of perfect elasticity theory to the Earth.

At places not too near an earthquake's epicentre—the " epicentre " is the point of the surface vertically above the focus—the *P* and *S* waves can be regarded as travelling out along rays, as in the case of light. The changing physical properties inside the Earth are accompanied by changes in values of the wave velocities, and cause the rays to be gradually curved inside most of the Earth. There are also places where abrupt changes of property cause the rays to be sharply bent or " refracted."

As a result of the bending, gradual and sharp, rays may emerge at the Earth's surface at all distances from an earthquake epicentre. In addition they can be reflected and refracted at boundaries into both *P* and *S* types, even when only one type is incident. From a single earthquake, rays may therefore reach a particular observatory by many routes. Thus in practice seismograms are usually highly complicated and show many

" phases," each corresponding to the arrival of a group of waves by one of the many possible paths.

One of the great efforts of seismologists over the first 40 years of this century was devoted to the unravelling of this tangle of phases on seismograms. Starting from extremely crude beginnings around 1900, there was a slow evolution of seismic travel-time tables, which give, for each separate phase, the times of travel along earthquake rays in terms of the angles the rays subtend at the Earth's centre. In 1940, Sir Harold Jeffreys and I completed a set of tables, called the J.-B. tables, which are at present used in compiling the International Seismological Summary, and which appear at least in the best instances to be accurate to a second or so in travel-times up to 20 minutes. Finer accuracy is now being attained through the use of seismograms of nuclear explosions which, whatever other properties they may have, can be looked upon as controlled earthquakes. In spite of being smaller than large natural earthquakes, they have a cardinal advantage in that the focus and origin-time are not concealed by Nature.

The travel-time tables constitute the most precisely determined seismological data we have. They supply the key to obtaining, by a nice piece of mathematical deduction, values of the velocities of the *P* and *S* waves throughout a large part of the Earth's interior. From the J.-B. tables of 1940, Jeffreys computed fairly reliable values of the *P* velocities throughout nearly the whole Earth, and of the *S* velocities down to a depth of 1,800 miles.

One of the most noticeable results of this research was the degree of independence of the travel-times on geographical region. This showed that the mechanical properties of the Earth are remarkably symmetrical about the centre. The outstanding deviations, which I shall ignore in to-night's broad sweep, are those associated with the Earth's ellipticity of figure, and various irregularities confined mainly to the outermost 25 miles or so.

The fact that the velocities vary mainly only with depth in the Earth enables us to chart the interior of the Earth out into a number of regions according to depth. The boundaries between regions are indicated by the levels at which the *P* and *S* velocity values, or their rates of change, show marked changes.

A number of the boundaries had of course been determined long before 1940, and I shall now give a brief sketch of the principal results.

In 1909, a Balkan seismologist Mohorovicić, while studying local earthquake records, found a marked velocity jump which he placed at some tens of miles below the Earth's surface. Later work by others showed this to be the first evidence of a marked change of property, now referred to as the Mohorovicić discontinuity, which occurs about 25 miles below the surface in all normal continental regions and 5 miles or so below ocean floors. The Mohorovicić discontinuity has received some publicity lately because of a project to bore a hole down to it, probably in a part of the Pacific Ocean where it reaches to within a few miles of the ocean floor.

The region above the Mohorovicić discontinuity is nowadays commonly called the " crust." Inside the crust, the *P* and *S* velocities are characterized by much more erratic variation than elsewhere in the Earth. When the term " crust " was first used by geologists, there was a suggestion that the Earth bears some resemblance to Robert Louis Stevenson's description of human character, as " a paste-board portico covering up a deliquium of deadly weaknesses within." The term now has, however, only a conventional meaning. We have learnt from seismology that the Earth has a solid " mantle " extending to a depth of 1,800 miles, in which the rigidity steadily increases with depth. The mantle is solid in the sense I have defined because *S* as well as *P* waves pass vigorously through all parts of it.

Below the mantle lies the Earth's " central core." The existence of the core was suspected last century, but the decisive seismological evidence was obtained (by Oldham) only in 1906. The depth to its outer boundary, namely 1,800 miles or 2,900 km., was first computed by Beno Gutenberg in 1913. Statistical work of Jeffreys in 1939 showed Gutenberg's figure to be accurate to 3 miles or so.

The discovery of the core came about this way. Consider a large hypothetical earthquake with focus say at the North Pole. The *P* waves issuing from it would be strongly recorded at all stations in the Northern Hemisphere, and, as well, in the Southern Hemisphere as far as latitude 15 degrees south, i.e. a little further south than Darwin. But between here and 52 degrees south, there would be a " shadow zone " in which the regular *P* waves would be very much subdued. At the latitude of 52 degrees south, they would come in strongly again and be well-recorded right down to the South Pole. Nearly all of Australia and New Zealand would thus lie inside the shadow for this particular earthquake. All large earthquakes have such shadows between angular distances of 105° and 142° from the epicentre.

It became apparent that the shadows must be due to the presence in the Earth of a large central core in which the velocity of *P* waves is sharply reduced, causing rays through the mantle to be refracted sharply downwards on meeting the boundary.

The next important result is that no *S* waves have ever been detected in the Earth's central core. This is a first clue towards showing that the greater part of the central core is in a fluid or molten state. The more complete evidence for this conclusion comes by taking other geophysical evidence into account, including such things as measurements of the tidal deformation of the solid surface of the Earth and astronomical observations related to movements of the Earth's poles. These measurements enable the overall rigidity of the Earth to be calculated. Allowance for the rigidity of the mantle, derived from values of *S* wave velocities in the mantle, then enables the rigidity of the core to be estimated. The calculation is a fearsome one mathematically, and the first precise solutions were obtained by the Japanese Takeuchi in 1950 and by the Russian Molodenski in 1953. Their work makes it clear that most of the core must be either fluid, probably molten, or else fairly close to this state.

. For many years after the discovery of the central core, the core was thought to be uniform throughout and to consist of homogeneous molten iron and nickel. Then in 1936 a Danish woman seismologist, Miss Lehmann,

looked more closely at records taken in the shadow zones of two New Zealand earthquakes. Before her work, it had been generally assumed that such small *P* waves as did emerge in shadow zones were due to diffraction effects round the core boundary. Miss Lehmann suggested, as an alternative explanation, the presence inside the main core of an " inner core " in which the *P* velocity jumps sufficiently to make some of the *P* rays which enter it bend steeply up and emerge inside the shadow. Gutenberg showed in California in 1938 that Miss Lehmann's hypothesis fitted all the travel-time data; and Jeffreys in 1939 put the existence of the inner core beyond reasonable doubt when he showed that, small though the waves in the shadow zone are, some of them are still too large to be reasonably accounted for by diffraction. Another link in the chain of evidence was supplied in 1957, when T. N. Burke-Gaffney and I were able in Sydney to demonstrate, from records of hydrogen-bomb explosions, the existence of diffracted waves separately from the inner core waves. The radius of the inner core is about 800 miles.

In 1946, I came across evidence pointing to the inner core being solid. This happened in the course of another study which indicated that compressibility in the deeper interior of the Earth varies remarkably smoothly with the pressure. The work made it necessary to attribute the jump in *P* velocity between the outer and inner core to a substantial rise in rigidity; and this could mean only that the inner core is solid. New evidence in the intervening ten or twelve years, including evidence adapted from theoretical physics, has all supported this conclusion.

The broad picture of the interior of the Earth as revealed by seismology is then that there is first the crust, a thin skin near the outer surface, part of a solid mantle extending down to a depth of 1,800 miles, then a fluid outer core of thickness 1,400 miles, and finally an inner core, most probably solid, of radius 800 miles. The seismological information goes further and enables some additional subdivisions to be made, but I shall not go into details of these to-night.

So much for the general layout of the Earth's interior. The next step is to assess the mechanical properties of the various layers.

For this purpose, the *P* and *S* velocity values are used in further detail. They supply two sets of well-determined data throughout the mantle on the three properties on which their values depend, namely, the density, incompressibility and the rigidity. The two sets of data can be extended to a depth of 3,200 miles, taking note of the fluidity of the outer core.

If there were a third such set of direct observational data on the incompressibility, rigidity and density, it would be a matter of elementary algebra to calculate all three of these quantities throughout much of the Earth. Unfortunately, the way is not as simple as this, as I found in 1936 when I needed knowledge of the Earth's density variation for another purpose. I found it necessary to bring to bear a wide variety of evidence, but finally derived density values which appear to be accurate to less than 0·5 down to the bottom of the outer core. At least, the figures have stood within that accuracy for the last 20 years or so.

I shall not here give any detail of the calculation, but mention the type of evidence brought to bear. First, the seismic velocity values, through their dependence on the compressibility, can be used in a further capacity to link the rate of change of density with pressure in some parts of the Earth. The theory of gravitational attraction then provides a second link between pressure, density and depth. Thirdly, there is some correlation between seismic velocities and densities in the outer part of the Earth as found by laboratory experiments on rock samples. Fourthly, a vital point which earlier investigators had not seen, consideration of the moments of inertia of concentric spheres of the Earth leads to powerful restrictions on the allowable density values, especially in the lower mantle and outer core.

On this basis, I constructed a solution in which the density rises from 3·3 just below the crust to 5½ at the bottom of the mantle. The density then jumps to 9½ at the top of the core, and reaches 11½ to 12 at the bottom of the outer core.

I did not manage at first to estimate the density in the inner core, but was able to show that the density at the Earth's centre must exceed 12·2. Much later, in 1950, in the course of my study of the Earth's compressibility, I found evidence favouring a density about 18 at the centre.

This last result has been queried by some geophysicists who would prefer a value near 13. But in the meantime another result has emerged which incidentally gives an interesting sidelight on the variety of the sources of evidence that can be brought to bear on the Earth's interior.

In 1952, a literally world-shaking earthquake occurred in Kamchatka in Eastern Siberia, which sent surface seismic waves many times round the Earth. Shortly beforehand, H. Benioff had set up, in a disused tunnel in a canyon in California, a new type of instrument designed to measure disturbances in rock-strain, instead of the usual ground displacement. Benioff had found that the Kamchatka earthquake had produced some extraordinarily long waves on the records of this new instrument, with two apparently well-defined periods of 57 and 100 minutes. It appeared that the earthquake had set the whole Earth ringing like a bell, so to speak.

Benioff's observations led C. L. Pekeris of Israel to work out the natural periods of vibration of the whole Earth. The results would of course depend on the assumed structure of the Earth's interior, and Pekeris used my model and a few others. He found that my model alone gave a fundamental and second mode of vibration that agreed with Benioff's periods of 57 and 100 minutes within the uncertainties. He also found that it did not matter whether he used a figure of 13 or 18 for the density at the Earth's centre, so far as the 57 minutes period was concerned, but that no period anywhere near 100 minutes was possible with a central density near 13.

On this evidence, it would appear that the figure of 18 for the density at the Earth's centre has a good chance of being about right. But we should like a few more real world-shaking earthquakes to be sure that Benioff's

observations are indeed genuine. Since the Kamchatka earthquake, there has been no other to date quite suitable for the purpose.

So much for the Earth's density values. In the same series of calculations, I also derived figures for the pressure, gravity, incompressibility and rigidity throughout the Earth.

As you know, the pressure of the Earth's atmosphere is about 15 pounds weight per square inch. This pressure is commonly taken as a unit and referred to as "one atmosphere." The pressure of steam in a locomotive reaches some 25 atmospheres. The pressure 5 miles below the surface of the Pacific Ocean is about 800 atmospheres. Professor Bridgman's laboratory pressure of 100,000 atmospheres is reached in the Earth at a depth of only 200 miles. At the bottom of the Earth's mantle, the pressure reaches the immense figure of 1½ million atmospheres, while at the centre of the Earth, the value lies between 3½ and 4 million atmospheres.

The results on g, the gravitational attraction per unit mass, are rather intriguing. The mean value at the Earth's surface is about 32·2 foot-second units. From here down to a depth of 1,500 miles it stays remarkably constant, never deviating by more than one per cent. from the figure of 32·4. It rises to its maximum of about 33½ at the bottom of the mantle and then sinks steadily to zero inside the core.

As regards the property of rigidity, it had been shown nearly a hundred years ago by Lord Kelvin that the Earth is on the whole twice as rigid as ordinary steel, and thus much more rigid than most surface rocks. The results from the seismic data and density calculations give the fuller detail. Inside the mantle, the rigidity, in respect of response to stresses of earthquake period, increases steadily until at the bottom it has nearly four times the value for ordinary steel. The value drops to something near zero in the outer core, and, if my theory of the solid inner core is right, rises there to two or three times the value for steel.

The incompressibility steadily increases downward throughout the whole Earth and at the centre has about ten times the value for ordinary steel.

The mechanical properties which I have referred to so far are the best-determined properties of the interior of the Earth. It is possible to say something about other properties such as temperature and the Earth's magnetism, but with much less quantitative precision.

From the fact that the mantle is not molten, R. J. Uffen of Canada showed in 1953 that the temperature at the bottom of the mantle is not likely to be much higher than 5,000 degrees. It could be as low as 2,000 degrees. Present estimates of the temperature at the Earth's centre range from about 2,000 to 10,000 degrees.

As regards magnetism, it seems that the principal source of the Earth's magnetic field arises from currents carrying electrical charges inside the fluid outer core. There are still some problems to be solved here, including the problem of finding an adequate source of energy to maintain the currents, but no other theory seems at all capable of explaining present observations. An incidental point of interest is that the theory requires for its success a boundary inside the main central core such as a solid inner core would provide.

It is also possible, with caution, to venture some comments on the Earth's internal composition. Laboratory experiments at high pressure when matched against the seismic data make it fairly certain that most of the mantle consists of either iron-magnesium silicate rock, or other ultrabasic rock, or possibly a chemically equivalent mixture of phases such as iron oxide, magnesia and silica. There may also possibly be a fair quantity to uncombined iron as well.

The question of the composition of the core is specially interesting. Up till 1941, it had been taken practically for granted that the whole core consists very largely of molten iron and nickel. This view was put forward by E. Wiechert of Göttingen around 1900 in order to explain the high density of the core. Also the idea received apparent support from early collections of meteorite samples, assumed to be representative of planetary material.

Then in 1941, two Swiss physicists put forward the radically different idea that the core consists of compressed hydrogen. This idea, which was based on their estimate of the time needed for original hydrogen to diffuse out from the Earth's interior, has since been shown to be quite untenable; but it had the virtue of stimulating some interesting calculations by theoretical physicists.

In 1946 it was calculated that at 700,000 atmospheres, the pressure existing about 1,000 miles below the Earth's surface, hydrogen would suddenly change to a metallic form and jump in density from 0·4 to 0·8. This result inspired a compromise theory between the iron and hydrogen core hypotheses, put forward first by W. H. Ramsey in 1948, to the effect that the outer core consists of the same chemical materials as the lower mantle, but in a high-density metallic state brought about by the huge pressure of 1½ million atmospheres; that pressure and not change of chemical composition is responsible for the jump in density from 5½ to 9½ at the bottom of the Earth's mantle. A core of this character would be no less compatible than an iron core with the theory of the Earth's magnetism, since it would have the electrical conducting properties of a metal.

It is at this point that the question of the structure of the planets becomes acutely relevant to that of the Earth, and I shall now branch off into a consideration of the terrestrial planets Mercury, Venus, the Earth and Mars, and also the Moon.

In 1937, Jeffreys and I, working from my density solution for the Earth, had independently concluded that the terrestrial planets must be considerably different in overall chemical composition. This conclusion rested, however, on the assumption, not challenged at the time, that the Earth's mantle and core are composed of the chemically distinct materials, rock and iron. The calculations showed that in order to fit the observed planetary masses and diameters on this assumption, the proportion by mass of mantle to core in Venus would have to be twice that for the Earth, and in the case of Mars 2½ times. There was no possibility of explaining these apparent discrepancies in composition by errors in the observational data or in the density and pressure values used.

Ramsey and I subsequently noticed that the contrary assumption, that the Earth's core is not chemically distinct from the mantle, would act in the direction of reducing the discrepancies. It would obviously permit Venus to have a proportionately smaller core than the Earth, since Venus being the smaller planet would have correspondingly smaller internal pressures, depth for depth, so that the pressure at which a core would be formed would be reached lower down.

Ramsey and I set to work on quantitative aspects of the idea in somewhat different ways, but the upshot in 1950 was this. Taking the Earth's outer core to consist of modified mantle-material and applying the density-pressure relation for the Earth to other planets, it is possible to calculate a value for the mass of any planet, given its diameter. When the calculations were carried out, it transpired that the results fitted the observed masses and diameters of both Venus and Mars practically within the standard errors. The fit was best when it was further assumed that the Earth's inner core is chemically different from the outer core and mantle. The results gave Venus an outer core much smaller than that of the Earth, and an inner core comparable with that in the Earth. In Mars there was no outer core at all, but a small core corresponding to the inner core of the Earth.

This was not the whole extent of the observational agreement. The moment of inertia of Mars is fairly well known from observations of its ellipticity of figure; and it transpired that the density distribution calculated for Mars fitted the moment of inertia as well as the mass.

This remarkable degree of agreement with the existing observations led us to think that we were well on the way towards solving the essential problem of the composition of the terrestrial planets. But around that time, the astronomers did a rather unpleasant thing. They reduced the observational value of the diameter of Mars by something like eight times a previously assessed standard error. This and some other changes made the agreement with our theory, while still quite fair, rather less striking than it had at first seemed to be.

Turning now to the innermost and smallest planet Mercury, the currently assigned mean density is about 5. Even though this is less than the value for the Earth, it requires the average material in Mercury, on any reasonable theory, to be denser, when reduced to zero pressure, than that in the Earth, because Mercury is so much smaller than the Earth. There is in fact little escape from the conclusion that Mercury must contain proportionately more iron than the Earth. This, however, is not necessarily an argument against our theory since Mercury is the closest planet to the Sun, with a temperature of several hundred degrees at the sub-solar point at perihelion. It thus seems reasonable to suppose that much of the original mantle of Mercury has volatilized away, so that the primitive Mercury may have had the same overall composition as the other terrestrial planets. The fact that Mercury appears to contain a great deal of iron incidentally lends support to the conclusion that at least the Earth's inner core must contain much uncombined iron.

The mean density of our Moon is between 3·3 and 3·4. Calculation then shows that any core the Moon might have is very small, and that there is, almost certainly, no fluid zone. The most likely composition of the Moon is that of the material in the outer mantle of the Earth. Perhaps we shall soon know this more definitely by direct sampling !

It would not be correct for me to imply that the phase-transition theory of Ramsey and myself on the composition of the Earth's core is other than controversial in the light of current evidence. However, in 1952, I was able to show that the representative atomic number for the material of the Earth's outer core is probably several units less than for iron—a conclusion which has been supported by L. Knopoff of California and others. This and related work makes it strongly probable that the Earth's outer core must contain at least a fair amount of material less dense at zero pressure than pure iron, but there is still divided opinion on the composition of such material. A difficulty in the phase-transition theory is that the density jump from $5\frac{1}{2}$ to $9\frac{1}{2}$ is rather larger than some theoretical physicists think could be explained in this way; at the same time, no one has yet managed to make sufficiently definite calculations to settle the matter. Experimental work may solve the problem within the next few years, and transitory pressures of the right order are now starting to be realized in laboratories.

I should mention too that geochemists have been active in putting forward various theories of the compositions of the terrestrial planets. One noteworthy theory is due to the Australian A. E. Ringwood, who also assumes the terrestrial planets to have been originally of uniform composition, but attributes the present differences in mean densities to chemical reduction. Some other chemists, for example Urey, have held that the overall compositions of the terrestrial planets were never closely identical. The various arguments are complicated, and what I have done to-night is to give you a glimpse of some of the work that is going on in this field. Obviously there is still a long way to go.

There is one intriguing consequence of the phase-transition theory that is worth mentioning. Ramsey showed that planets with small cores brought about by phase transition can in certain circumstances be dangerously unstable. Removal, even if slow, of matter from the surface of such a planet, and the consequent lowering of the pressure inside, could cause a small high-density core to revert to the low-density phase with explosive violence. Ramsey has shown that Venus is close to the dimensions of a planet in which such a catastrophe could occur.

A related calculation by A. N. Datta and myself shows further that a primitive single Earth-Moon body, containing a small additional core no longer present, could have had enough surplus energy to have ejected a quantity of matter equal in mass to the present Moon. There are, however, dynamical difficulties in assembling the particles after ejection to form a body of the Moon's size, so that at present the odds are somewhat against the Moon having been actually formed in this way.

It remains for me to comment on the structure of the outer planets. The question of their internal composition was attacked by Kothari and Wildt in 1938, and

later by Ramsey who made direct use of the 1946 calculations on the behaviour of hydrogen. To a first broad approximation, the case of some of the major planets admits a more definite answer than that of the inner planets. The reason is that the outer planets are so much less dense than the Earth that the choice of their principal constituents is much more restricted.

Ramsey started by calculating the variation of density of hydrogen with pressure right through to the very great pressures reached in the interiors of the large planets. At zero pressure the density of liquid hydrogen is 0·09. It has increased to 0·4 near 700 thousand atmospheres, where there is the phase change to metallic hydrogen of density 0·8. Thereafter, the density steadily rises with pressure, and reaches the figure of 3 at about 30 million atmospheres.

Ramsey used these figures to show that the two most massive outer planets, Jupiter and Saturn, whose mean densities are 1·3 and 0·7, must consist predominantly of hydrogen. His calculations, which take account of the planets' observed masses and moments of inertia, show that nearly 80 per cent of the mass of Jupiter must consist of hydrogen, also that there must be a metallic core, mainly of hydrogen, reaching five-sixths of the way from the centre to the surface.

In Saturn, about two-thirds of the mass is hydrogen, and the core reaches about two-thirds of the way to the surface.

The other two major planets, Uranus and Neptune, are appreciably smaller than Jupiter and Saturn, so that if they also consisted mainly of hydrogen their mean densities should be well below those of Jupiter and Saturn. This is not the case, however, the actual values being about 1·3 and 2·2, from which it follows that Uranus and Neptune have proportionately smaller hydrogen contents. In all four major planets, the main ingredients other than hydrogen are likely to be methane, ammonia and water, and the last three appear to predominate in Uranus and Neptune.

The calculations incidentally allow the possibility that the four major planets contain kernels composed of the same materials as the Earth, and perhaps as large as or larger in mass than the Earth. Thus the entire set of planets could possibly have had the same original overall chemical composition, the present differences being due to varying losses by escape of lighter ingredients. This, however, is getting on to speculation beyond present possibilities of testing.

Such is the present broad state of knowledge, as I see it, of the internal constitutions of various members of the solar system. For the most part, I have kept to questions which have specially interested me in my own researches, but I have tried to present as balanced a picture as possible. I have tried to show how some of the knowledge is very definite, some a little hazy, and some highly controversial.

A natural question to ask is whether increased knowledge can be expected through the current sensational advances in space exploration. The answer to this question would appear to be a decided "yes." The advances can be turned to provide us with new knowledge not only about the interiors of distant planets, but also about the interior of the Earth itself.

The most immediate result to be expected is decisive knowledge on the size of any magnetic field around the Moon. On the evidence I have presented to you tonight, it is highly improbable that the Moon contains an internal fluid zone. This makes it also improbable that the Moon has a magnetic field comparable with that around the Earth. A press report last week actually stated that observations just made by the Russians show the Moon's magnetic field to be negligible. If this report proves to be correct, there is observational confirmation of an important section of our thinking on planetary interiors. If, on the other hand, the report should prove to be false and the Moon be found to have a sizeable magnetic field, then we might have to rethink our ideas on the Earth's magnetism, with possible repercussions on some of our ideas on the Earth's composition.

Next there is the possibility that details of the path of a satellite put into orbit around Venus could lead to information of value on the moment of inertia of Venus, on which we at present have no observational data. Such information would give a useful check on the size of a core in Venus and again enable us to make comparisons with the Earth. This procedure would, however, depend for its success on Venus spinning rapidly enough to have an equatorial bulge like that on the Earth; we do not as yet know whether that is the case.

An obvious and more sure type of experiment, now approaching the bounds of possibility, is to produce a number of precisely-timed sizable explosions on the surfaces of planets, sufficient to send seismic waves through their interiors. This could be done right now, but a further requirement is the setting up of recording instruments at appropriate points of the planetary surfaces, each capable of transmitting to Earth the precise time of arrival of the first seismic pulse from an explosion. By this means, we could chart out the interiors of the Moon, Mars and Venus by the same procedures that we have used with the Earth. In particular, knowledge of the precise size of the core of Venus, or of the existence or absence of cores in the Moon and Mars, would be of profound importance to theories on the composition of the Earth's core.

There is, however, a new type of difficulty to be faced with this type of experiment. A number of scientists have become concerned with the possibility that various planned activities outside the Earth may prejudice other classes of experiments. This concern has led the International Council of Scientific Unions to set up a Committee called CETEX—"Committee on Contamination by Extra-terrestrial Exploration." The Committee, in a recently published Report, urges that "scientists plan lunar and planetary studies with great care and deep concern so that initial operations do not compromise and make impossible, forever after, critical scientific experiments." The Committee urges that, to begin with, scientific vehicles make their observations by circuiting the various planetary bodies without landing, so far as possible, in order to cause the minimum interference to the existing state of affairs. The notion of having sizable explosions on the surfaces of the Moon and planets is placed well down on the priorities.

Thus some time may elapse before the suggested experiments are carried out. How long the time will be, I should not care to guess. This is a fast-moving World—or perhaps I should say Solar System—that we are living in. Meanwhile, I hope I have given you a useful glimpse of some aspects of our present state of knowledge of it.

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THE ANNUAL DINNER

Park Lane Hotel, Piccadilly, London,

May 3, 1960

The principal guest is Sir Roger Makins, Chairman of the United Kingdom Atomic Energy Authority, until recently Joint Permanent Secretary of H.M. Treasury and formerly British Ambassador to the United States of America.

Tickets (exclusive of wines) are two guineas each. Graduates under the age of 25 years, and Students of the Institute may have either one or two tickets at 30s. each.

Forms of application for tickets will be circulated with the February *Bulletin*.

Practical Courses in Nuclear Physics

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INTRODUCTION

In addition to the normal physics laboratories of a university institution, the Royal Military College of Science possesses a pair of specialized nuclear laboratories, the more elaborately equipped of which has been fully described elsewhere.(1) The Rutherford laboratory and its annexe are designed to handle a very wide range of students and the equipment and experiments are chosen and deployed to give much flexibility according to the purpose and intellectual level of the courses from beginners to postgraduate students. For this reason it should be useful to make the experience gained in running this laboratory over a period of approximately three years accessible to those who are for the first time planning or running courses in nuclear science and technology.

The Rutherford laboratory is equipped in the main with commercial apparatus. Physics honours students have their first-principles training, using less sophisticated equipment elsewhere, and then join the specialized laboratory to learn the modern techniques of handling and using radioactive material and their radiations. Nevertheless, with all students, the courses include experiments so conducted that there is worthwhile thinking to be done : mere training in technique is avoided.

Those who have read the description of this laboratory appreciate that the Physics laboratories are adjacent to the Radiochemical laboratories and this is very advantageous for much of the work.

PLAN OF COURSES

In this article, a selection of experiments is grouped under appropriate section headings in Table I and described, in the same sequence, in the text. Many of these experiments are adaptations of those given in standard textbooks and in some instances, several obvious variations are possible.

The aim of each practical course in nuclear physics is to familiarize the student with the modern methods of detection of nuclear radiations, the interactions of the radiation with matter, the health precautions associated with radioactivity and the practical uses of radioisotopes. It has been found advantageous to preface such work with some atomic physics, such as the determination of some of the atomic constants used with such contemptuous familiarity in the nuclear physics instruction. These preliminary experiments, included in Table I, take place in the annexe laboratory as there is no radioactive hazard and special health precautions are unnecessary. A few electronics experiments could be included in this section if it were necessary.

TABLE I

Introductory—Atomic Physics
1. Determination of the ionization potential of a gas.
2. Determination of "e" (Millikan's Oil-Drop Method).
3. Determination of "e/m".
4. Determination of Planck's Constant "h".

Health Physics
1. Determination of β-γ dose and the calibration of dose and dose-rate meters.
2. The calibration of film badges.
3. The monitoring of contaminated ground.

Detection of Radiations
1. The measurement of ionization current.
2. The Geiger-Müller counter and counting statistics.
3. The scintillation counter.

The Properties of Radiations
(a) *α rays:* The range of α-rays in air.
(b) *β rays:* (i) The range of β-particles.
(ii) The back-scattering of β-particles.
(c) *γ rays:* (i) The absorption coefficient of lead, copper, etc.
(ii) The Compton scattering by lead.
(d) *neutrons:* The determination of thermal neutron flux in water.

The Properties of Radioactive Isotopes
1. Preparation of a source by neutron irradiation and half-life determination.
2. The determination of the decay curve of a composite emitter (Ag).
3. The β-spectra of isotopes.
4. The γ-spectra of isotopes.

Miscellaneous
1. Radiography—a comparison with X-rays.
2. The use of nuclear emulsions.

APPARATUS

The laboratory has several standard counting equipments, each comprising a Geiger counter fixed in a castle, pre-amplifier and scaler, with e.h.t. supplied from external power packs. In addition, there are more portable Geiger counter assemblies available with scaler or ratemeter attached. Ionization chambers, hand monitors and other methods of assessing sources and radiations are available. There is a neutron source capable of inducing measurable activity in suitable

materials in a reasonable time and there are chemical facilities for the preparation of experimental sources from larger sources obtained from the Isotope Division, Harwell, or the Radiochemical Centre, Amersham.

With the wealth of facilities available, care must be taken to see that the students' ability is challenged, otherwise experiments could readily degenerate into exercises in manipulative technique and in operating counters. On the other hand, only in a laboratory of high standard can the discipline, inseparable from good handling technique, be readily inculcated in students spending short times in the laboratory.

INTRODUCTORY ATOMIC PHYSICS

These experiments are based on the well-known methods described in the textbooks. The ionization potential of argon is measured by using a thyratron as a gas-filled triode in the manner of Lenard's early experiments.(2) The onset of ionization, when the potential between the grid and cathode is equal to the ionization potential, is clearly shown by the collection of positive ion current by the anode which is maintained at a small negative potential. The determination of the charge on an electron using Millikan's oil-drop method is a long experiment necessitating careful and patient observation of a single charged drop.(3) For advanced students the determination of the lowest common multiple of the changes in charge shown by the drop over a long period is used to find "e"; other students assume the value of "e" and determine the number of charges on one or more drops. The ratio e/m for an electron is determined by using the modification of Busch's "helical" method.(4) This involves the focusing of a fine beam of electrons in a small cathode ray tube inserted in a solenoid which provides the focusing magnetic field. For elementary students the associated circuitry, which is somewhat complex, is wired ready for use and the interelectrode distances in the cathode ray tube are given, whilst advanced students connect the circuit and measure the distances required. For the determination of Planck's constant the ratio "h/e" is measured using retarding potentials to determine the cut-off potential required to reduce to zero the photoelectric current produced by different optical wavelengths in a vacuum photo-cell. The apparatus includes a prism spectrometer, used as a monochromator, and a vibrating reed electrometer to measure very small photocurrents. The experiment takes a long time and is generally reserved for advanced students, although it is used for demonstration to elementary courses.

HEALTH PHYSICS

The importance of this topic is emphasized in the construction of the laboratory so that from the outset the student is aware of the precautions which must be taken to avoid the ill-effects of nuclear radiations. Before proceeding to any experiment each student must report to the laboratory office to collect a personal film-badge and don white overalls as protective clothing. At the conclusion of an experiment each student must pass through the monitoring room associated with the laboratory and check carefully his clothing, hands, feet, etc., for contamination, using the β-γ probe of a radiation monitor. After this the student must report once more to the office, handing in the used film badge. By this means a record is kept of the time spent by each student in the laboratory and the doses recorded by the film badge related to the experiments performed. Furthermore, the sources used in the laboratory are carefully checked before and after an experiment to ensure that no source is mislaid and becomes an unseen potential hazard.

The experiments in health physics are concerned with the measurement of radiation dose and dose-rate, using standard laboratory and civil defence type of equipment. A standard γ-ray source consisting of five millicuries (5mc) of radium supplied by the Radiochemical Centre, Amersham, is used to calibrate a quartz-fibre dosemeter, pocket ionization chamber and an ionization chamber type of dose-rate meter. These, in turn, are used to determine the β- and γ-dose at various distances from a composite source of strontium 90 and radium. Finally, a source of 5mc of cobalt 60 is used to calibrate a standard Geiger-Müller counting-rate type of monitor in terms of millirontgens of γ-ray dose per hour. Students are always amazed at the very low γ-dose rate required to give a large noise on the monitor. The experiment is capable of curtailment by excluding the calibrations of the various meters or by taking one check reading rather than several as normally required from advanced students.

The calibration of film badges introduces students to the range and limitations of the most common health physics personnel monitor. At the same time the student is familiarized with the technique of photography, later required for radiography. A source consisting of 20mc of ^{60}Co is used as a standard γ-emitter. The dose-rate at one foot from this source (R) is given to a sufficiently good approximation by the formula : $R = 6EC$ rontgens per hour, where E is the total energy in MeV of the two γ-quanta emitted ($E = 1{\cdot}2 + 1{\cdot}3 = 2{\cdot}5$ MeV), and C is the source strength in curies. Film badges are arranged at various distances from the source and left for a known time (20 mins.), so that with the aid of the inverse square law the total dose received by each film is determined. The development, fixing and drying of the films is conducted in the small dark room attached to the laboratory. The drying of the films is considerably accelerated by using a home-made warm-air drying cabinet. The relative blackening of the films is determined in a very simple manner, by using a barrier-layer photocell in conjunction with a galvanometer to measure light transmission. The dose recorded by films placed in various parts of the laboratory are determined from a curve of blackening $v.$ $\log_{10}$ (dose), constructed for the type of film used. This experiment is not difficult but time is consumed in the dark room and for elementary courses assistance in rapid development and drying is essential. Care is needed in handling the relatively large cobalt source and advanced students who are required to place the source in position, use remote handling tongs for this purpose. Monitoring and tests of shielding efficiency are also carried out by advanced students.

The last experiment in this section is designed to teach the elements of radioactive survey of contaminated ground. The instrument used for this purpose is an

ionization chamber survey meter (type 1390) designed for the accurate determination of dose-rate over a very wide range. The contaminated ground is the grass-covered space between the Rutherford laboratory and the Rutherford Annexe, measuring 30ft by 80ft approximately. Several sources consisting of 5mc of ^{60}Co (type "D" sources) are buried beneath the surface. The γ-radiation produced by these sources and that emanating from the antimony-beryllium neutron source housed close to the outer wall in the Rutherford laboratory, provide a radiation pattern which can be mapped with the aid of the monitor carried at waist level. Elementary students are not required to draw extensive contours but merely plot the positions of the hidden sources.

DETECTION OF RADIATION

The aim of these experiments is to acquaint the student with modern methods of determining the strength of radioactive sources. The first experiment in the group is short and introductory, having as its object the measurement of the variation of ionization current with voltage. A source of ionizing radiation, viz. 5mc of polonium (RaF), is placed at a fixed distance from the outer grid electrode of a small home-made ionization chamber. The air inside the chamber is ionized by the α-rays from the polonium and the small current collected at the flat inner electrode is measured by a vibrating-reed electrometer. A plot of ionizing current against the p.d. between the chamber electrodes gives a characteristic curve indicating saturation.

The main experiment in this section is an omnibus one illustrating the characteristics and use of the Geiger-Müller counting tube. A standard counting unit is used consisting of end-window β-γ Geiger tube housed in a lead castle with pre-amplifier and Dekatron scaler. A "reference" source of uranium oxide (U_3O_8), giving approximately 10^4 counts per minute, is first prepared by the students by evaporation, under an infra-red lamp, of a water-U_3O_8 slurry. This source is covered with aluminium foil to absorb the β-radiation and make it more robust. With this source the characteristic curve giving the variation of counting rate with e.h.t. is first determined for the particular counting tube used. The correct operating potential for the counter is deduced from the plateau of the characteristic. The paralysis time of the tube is determined by using two similar U_3O_8 reference sources[5] and noting the counting rates when each source is used alone and together. The background corrections are carefully determined for each reading, since the difference between counting rates is involved in the expression for paralysis time. The importance of statistics in determining counting rates is emphasized in a final experiment.[6] A large number of two-minute counts is taken with the source fixed in the castle. The frequency distribution of the observed counting rates is shown to be approximately normal.

The growing popularity of the scintillation counter as a detector has led to the introduction of an experiment on the determination of the characteristic curves of counting rate against e.h.t. for various bias voltages. In addition, the efficiency of the counter as a γ-ray detector is roughly compared with that of the Geiger counter by using a weak source of caesium 137.

It is found, in practice, that insistence on the determination of too many characteristic curves for counters, which involves the observation of a large number of counting-rates, leads to student fatigue and boredom. This is probably accentuated by the fact that the black boxes of electronics soon lose their glamour and become soulless and silent machines. Apart from setting-up the counter in its castle, there is little practical physics to do and care is taken to ensure that these experiments do not follow too closely on the heels of each other. It is very easy to arrange for both the counting experiments to be modified so as to take two hours or six hours to suit various courses. For elementary courses the preparation of source and determination of Geiger-characteristics is a sufficiently good introduction to the use of the Geiger-counter with scaler. The experiment on statistics is performed by advanced students only, whilst the paralysis time determination is a short experiment capable of being done and understood by intermediate and advanced students. The experiment on scintillation counting is reserved for the advanced students who understand the physics involved in this method of counting. For others the use of the counter is best illustrated in a lecture demonstration.

THE PROPERTIES OF NUCLEAR RADIATIONS

(a) *α-rays*

Two of the most important properties of α-rays, viz. their high specific ionization and their range in air, are dealt with in an experiment which is a modification of the Bragg method for measuring range.[7] In this experiment a home-made "shallow" ionization chamber, consisting of a grid electrode charged relative to a carefully insulated disc electrode with a separation of 1 mm between the two, is used to measure the specific ionization of a collimated beam of α-rays emitted by a 5mc polonium source. The small ionization current is measured with a vibrating reed electrometer instead of a quadrant electrometer used in the original Bragg experiment. The ionization current is plotted as a function of the distance between source and chamber and the characteristic Bragg curve, showing a maximum specific ionization towards the end of the range, is readily reproduced ; the actual range in air is obtained by extrapolation of the final linear part of the curve. A rough measure of the specific ionization is obtained by measuring the ionization current recorded by a bare polonium source at a suitable distance from the ionization chamber. From the source strength and solid angle subtended at the chamber the number of rays entering the latter is estimated. The electrometer reading, which is in millivolts, is converted into amps., providing the value of the high resistor used for current measurement is known, and hence the number of ion pairs formed per ray in the path between grid and collecting electrode of the chamber is determined.

Since α-rays are easily absorbed by matter it is difficult to perform simple experiments on stopping power. In this laboratory "mylar" film of various thicknesses have been used to produce a series of absorbing screens which can be used to determine the stopping-power.[8]

The polonium sources used in α-ray experiments and demonstrations are extremely dangerous. They are

provided by the Radiochemical Centre, Amersham, with a thin coating of varnish forming a seal which is easily broken by contact and may be damaged by continual α-ray bombardment. When this happens the polonium is likely to "creep" and cause serious contamination on neighbouring apparatus. The health hazard is potentially high, owing to the danger of ingestion via the hands. When this experiment is performed the students are required to monitor all apparatus, hands, overalls, etc., with the α-scintillation probe which is operated from the 1021-type counter.

(b) *β-rays*

The range of β-rays and the back-scattering of β-rays are the two properties of this type of radiation which form separate experiments of variable duration. In the experiment on range[9] a source of phosphorous 32 is used which is prepared by evaporation of a drop of the diluted orthophosphate solution on a standard planchette. The counting rate is measured as aluminium absorbers of known thickness are inserted between the source and end-window Geiger-Müller counter housed in a standard lead castle. The plot of $\log_e$ (counting-rate) against absorber thickness in mg.cm^{-2} is a characteristic one (Fig. 1). The ultimate linear part of the curve, caused by the truly exponential absorption of the γ-rays (bremsstrahlung) created by decelerated β-rays,

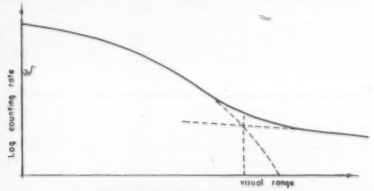

Fig. 1. *Typical β-absorption curve.*

may be extrapolated back and a more correct β-absorption curve drawn by subtraction. The range of the β's is given to a good approximation by the absorber thickness corresponding to the intersection of the bremsstrahlung line with the plotted curve, as shown.

With the source provided, this experiment lasts about three hours. A refinement, which is required of the advanced students, is the construction of a Feather "analyser," using another source giving a well-known absorption curve.[9] Thallium 204 is used for this purpose and a value of its range assumed. By comparing fractional ranges for the ^{204}Tl and ^{32}P curves a more accurate value for the range of the β's from ^{32}P is obtained.

The back-scattering of β-rays forms the basis of a method for measuring the thickness of tin coatings on steel, etc. ; the variation of scattered intensity with thickness of scatterer and the atomic number of the scatter is studied by using a ^{32}P source evaporated on to an aluminium ring.[10] The scattered rays pass through a hole in the source to reach the end-window counter as shown in Fig. 2. The tendency of the scattered radiation to saturate at a definite thickness of absorber and the variation of this saturation thickness with the atomic number Z, are deduced from appropriate graphs. This experiment may be lengthened or shortened to suit almost any class of student.

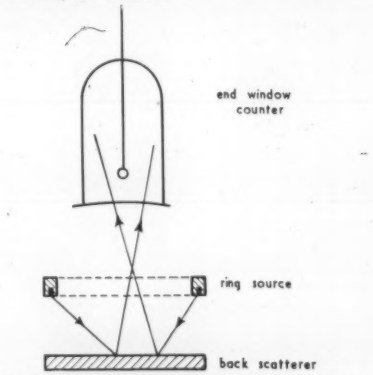

Fig. 2. *Diagrammatic arrangement of source and back scatterer.*

(c) *γ-rays*

The interaction of γ-rays with matter is very important because of their large penetrating power. In the experiment on the determination of absorption coefficients a collimated beam (" narrow-beam " geometry) is used, so that a reproducible straight-line graph of $\log_e$ (counting-rate) *v.* absorber thickness is obtained. The departure from exponential absorption is illustrated in a subsidiary experiment using non-collimated radiation (" broad-beam " geometry). In the simpler version of the experiment an ionization chamber type hand monitor is used since this allows fairly rapid readings to be obtained. In the longer experiment an end-window Geiger counter and scaler are used. The absorbing materials are lead, copper, aluminium and glass. The γ-radiation is obtained from a 10mc ^{60}Co source housed in a lead pot. A hand monitor is used to check on stray radiation causing a health hazard and producing a spurious background in the laboratory.

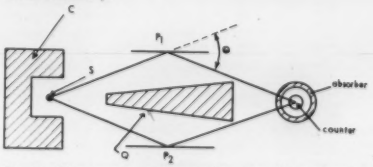

Fig. 3. *Diagrammatic arrangement of Compton change of wavelength.*

The experiment on the Compton change in wavelength produced in γ-radiation scattered back from a lead sheet is reserved for more advanced students. The arrangement used is similar to that suggested by Pollard and Davidson.[11]. In Fig. 3, S represents a 5mc ^{60}Co

wire source fixed vertically, just inside a standard rectangular lead castle C. With the front-"door" of the castle removed, a beam of γ-rays diverges outwards outwards and is scattered by the two lead sheets P_1 and P_2. The scattered radiation is received by the tubular Geiger counter GM, which is mounted vertically. The counter is shielded from the incident beam by the wedge of lead Q. The angle of incidence of the primary beam striking P_1 and P_2 is defined by the positions of these sheets, which are symmetrical about the line joining the counter and source. The angle of scattering (θ) varies between limits defined by the extent of the absorbers. The Compton change of wavelength is given by: $\Delta\lambda = \frac{h}{mc}(1-\cos\theta)$, and a measure of this is obtained by determining the counting rate for various thicknesses of thin cylindrical lead absorbers placed around GM. The absorption coefficient is determined from the $\log_e$ (counting-rate) *v.* absorber thickness and the γ-ray energy, and hence wavelength corresponding to this coefficient, is obtained from known data. The experiment is necessarily approximate because of variation in θ with the size of plates (20 cm × 20 cm) required for obtaining reasonable counting rates. As with the previous experiment, careful monitoring of the surrounding area is very necessary.

(d) *Neutrons*

This laboratory has two neutron sources, the larger one being an antimony-beryllium mixture. This is housed in a drum of paraffin wax inside an assembly of interlocking concrete rings. It is normally supplied with a nominal γ-ray activity of 1 curie, but, owing to the 60 day half-life of the active antimony 124 component, it has to be replenished every three or four months. This source is used mainly for producing small quantities of radioactive sources by the neutron capture (n,γ) reaction, the inactive material being placed in long aluminium tubes which are suspended in holes passing through the upper concrete shield and into the paraffin drum. The shielding on the side of the source nearer to the laboratory wall is relatively small and the γ-radiation which is transmitted through the wall provides a radiation field for the γ-ray survey experiment.

The second neutron source is a radium-beryllium mixture whose associated radioactivity is twenty millicuries. This source is suspended by thin wires in a large tank of water. An estimate of the slow neutron flux produced at various distances from the source is obtained by determining the β-ray activity produced in thin indium foils placed in a small aluminium holder inserted in the tank. The β-activity produced by resonance effects is obtained by using cadmium shields in the usual manner.[12] A special source holder which ensures 2π geometry is used in the castle of the counting arrangement and several assumptions are made in deducing absolute activities in order to determine the neutron flux. The experiment is a long one because of the small induced activity and the relatively long time required to obtain a saturation activity in the indium foil (half-life of ^{116}In = 54·1 mins.). It is hoped to improve this experiment by providing a larger neutron source.

THE PROPERTIES OF RADIOACTIVE ISOTOPES

As mentioned above, small quantities of active isotopes can be produced by the larger neutron source. In the experiment on half-life determination radioactive iodine is produced by irradiating methyl iodide in the neutron source. The Szilard-Chalmers reaction allows the active iodine to be separated as a silver iodide precipitate.[13] This source is very convenient to follow with a ratemeter because of its half-life (25 mins approx.). For quick experimentation the iodine source can be prepared for the student but it is preferable for students to perform the chemical separation themselves.

The irradiation of a silver foil in the larger neutron source produces two silver isotopes with half-lives of 2·3 minutes and 24 seconds so that a 10-minute activation time is sufficient to produce saturation activity. With alert removal of the foil from the activation tube and rapid insertion beneath an end-window counter attached to a ratemeter, a composite decay curve of the two silver isotopes is obtained. The longer lived isotope is solely responsible for the latter part of the $\log_e$ (counting-rate) *v.* time curve and its half-life is obtained immediately from the slope of this part of the curve. When this linear part of the curve is extrapolated back to zero time the counting rates corresponding to the shorter lived isotope are obtained by subtraction from the initial part of the curve and a new decay curve plotted for this isotope only. The short half-lives of the silver isotopes permit a decay curve to be drawn within half-an-hour. The experiment may be extended to determine the total activities of each isotope produced for different irradiation times. Some experience in manipulating the time constant control of the ratemeter to follow the counting-rate is essential for constructing good composite decay curves and dummy runs are recommended.

The spectrum of a β-ray emitter is characteristic of the source and a practical determination is of immense theoretical importance. The β-ray spectrometer used in this laboratory is essentially simple in design and is intended to illustrate the method of β-spectrometry rather than the accurate determination of spectra. The spectrometer is of the "thin-lens" type and based on a design suggested by Pollard and Davidson.[14] The β-emitter, deposited on a mylar film covering a hole in standard planchette, is placed at one end of the spectrometer tube and an end-window Geiger counter at the other. The thin-lens surrounds the middle part of the tube and is energized by a direct current. The tube is evacuated by means of a rotary pump only and counting rates are plotted as a function of the current producing the focusing magnetic field. The curves obtained for different sources such as ^{114}In, ^{137}Cs, ^{32}P, RaD, ^{90}Sr, etc., give the continuous β-spectrum with superimposed internal conversion spectra where appropriate. The difficulty associated with this rather long experiment is the calibration of the instrument, i.e. the transformation of focusing-coil current into β-ray energies. This is achieved by assuming linearity between coil current and β-ray energy and assuming the energies of well-known spectra such as the γ-conversion lines of the ^{137}Cs and ^{114}In sources.

The determination of the γ-ray spectra of radioactive isotopes is made by using a scintillation counter with discriminator and single channel pulse analyser. The apparatus used is a complex array of electronics and as such the experiment is reserved for advanced students. Various γ-ray sources, such as ^{137}Cs, ^{60}Co, ^{69}Zn, etc., are used and a plot of counting rate as a function of discriminator bias voltage "swept" by the pulse analyser is obtained from the scaler connected to the latter. Each source gives a characteristic curve on which the photo-electric peak corresponding to the γ-rays absorbed in the scintillation crystal is easily distinguished. By using several known simple emitters a spectrometer calibration curve of γ-ray energy *v.* discriminator voltage is constructed and the energies of γ-rays corresponding to photo-peaks of unknown sources are determined.

MISCELLANEOUS

γ-Radiography

The relative merits of X- and γ-radiography are illustrated in an experiment in which a hospital X-ray set and an iridium 192 source are used to produce radiographs of steel, aluminium and wood step wedges. With the X-ray set working at something like 40kV., the photographic contrast obtained with the different wedges for X-rays (minimum wavelength = 0·3Å approx.) and γ-rays (minimum wavelength = 0·0275Å approx.) is studied. From such considerations the better choice of radiation can be made for the radiography of two widely different objects, such as a fuze having a brass cover of thickness varying between $\frac{1}{4}$ in. and 1 in. and a quartz dosimeter which is essentially a light alloy tube of approximately $\frac{1}{16}$ in. thickness. This experiment does not lead to any measurements but serves only as an introduction to radiographic techniques. It may be reduced to the operation of taking γ-radiographs only or extended to include radiography with a thulium 170 source—this latter is extremely useful for light alloy structures such as valves, etc. The ^{192}Ir source used has a 2c strength when fresh (half-life = 74·4 days), and this gives suitable exposures with most objects within one hour. The ^{170}Tm source has a strength of 500mc when new (half-life 124 days), and this requires exposures of several hours.

Nuclear Plates

The use of nuclear emulsions for the detection of charged particle tracks is a specialized topic but the technique for some applications is simple and the pictures obtained are very instructive. Unfortunately, the operations involved in producing a negative involve long fixing and washing times, which render a complete experiment, involving the production of a plate and its interpretation, impossible within a normal practical class. For honours degree students the time factor is not important and the experiments suggested by Cook and Duncan[15] are admirable. It is doubtful whether a curtailed experiment in which students are given the developed plates to interpret is worthwhile as an exercise in practical physics.

CONCLUSION

The experiments described above have been performed in conjunction with other experiments involving chemical manipulation conducted by the Chemistry Department of this College. These additional experiments, which are carried out in a laboratory adjacent to the Nuclear Physics Laboratory, complete a balanced practical course in nuclear science. All the theoretical courses in nuclear science conducted by the College are comprehensive in the sense that they include contributions from the physics, chemistry, metallurgy and engineering branches, the major teaching being in physics and chemistry. The aim of such courses is to lead to an appreciation of the problems involved in the military and peaceful uses of nuclear energy. It is hoped that in the near future additional experiments illustrating metallurgical and engineering applications will be incorporated in the more advanced practical nuclear science courses.

ACKNOWLEDGEMENTS

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Notes and News

Proceedings of Extraordinary General Meeting

AMALGAMATION OF THE INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY

An Extraordinary General Meeting of the Institute was held on 1 December, 1959, at the Institute's House. The President (Sir George Thomson, Hon.F.Inst.P.) was in the Chair. Thirty-three Fellows and Associates being present, the Secretary read the notice convening the meeting.

After the President had briefly reminded the members present of the purpose of the meeting he proposed and Mr. O. W. Humphreys (*Past President*) seconded the following Special Resolution:—

> "That the scheme for the amalgamation of The Institute of Physics and The Physical Society proposed in the document circulated to members on 7 August, 1959, with the amendments which have subsequently been approved by the Board of The Institute of Physics and the Council of The Physical Society and which are set out hereunder be and is hereby approved and adopted.
>
> And the Board of the said Institute and the Council of the said Society are hereby requested to take the necessary action to implement the proposals therein."

AMENDMENTS TO SCHEME

(*The paragraph numbers refer to those in the scheme as set out on pages 7 to 16 of the booklet issued on 7 August, 1959*)

Amendment 1: That in paragraph 1 after the word "company" the following words be added: "limited by guarantee and without a share capital."

Amendment 2: That at the end of paragraph 2 the following words be added: "Each year a sum not less than the total of the annual subscriptions of Fellows of The Physical Society who are not Fellows, Associates or Graduates of The Institute of Physics will be transferred from the general funds of the new company to The Physics Trust Fund.".

Amendment 3: That in paragraph 4 after the words "Great Britain" delete the comma and insert the word "and" and also transfer the words ", the Isle of Man and the Channel Islands," to follow the words "United Kingdom" at the end of the sentence.

Amendment 4: That in paragraph 4 the words "and recommendations for election to or transfer to these grades of membership and to the Student grade" be added at the end of item (i) of "Professional matters".

Amendment 5: That in paragraph 5(*e*) the words "or to subjects connected therewith" be added after the word "physics".

Amendment 6: That the words "at meetings of the Institute and Society" be deleted from paragraph 5(*f*) and the words "or in subjects connected therewith" be added after the words "physical research".

Amendment 7: That in paragraph 5(*g*) the words "or otherwise reproduce" be added after the word "print" and the words "or to subjects connected therewith" be added after the word "physics", and the words "as shall be in a foreign language" be deleted from this paragraph.

Amendment 8: That in paragraph 5(*h*) the words "or loans" be added after the word "grants".

Amendment 9: That in paragraph 5(*i*) the words "or are interested in physics or in subjects connected therewith" be added to the end of the paragraph.

Amendment 10: That in paragraph 5(*j*) a comma be inserted before the words "and otherwise.".

Amendment 11: That the first sentence of paragraph 11 be deleted and the following be substituted therefor: "To be elected to membership in the grade of Fellow of The Physical Society a person will have to be at least 21 years old and to have obtained a degree or diploma recognized by the Council for the purpose or possess such a knowledge of physics and cognate subjects as shall be considered appropriate by the Council. In addition every member who is not already a Fellow of The Physical Society will upon election or transfer to membership in the grade of Fellow, Associate or Graduate of The Institute of Physics automatically become one.".

Amendment 12: That the first sentence of paragraph 12 be deleted and the following be substituted therefor: "The list of degrees and diplomas recognized for the purpose referred to in paragraph 11 will include all those on the list of degrees and diplomas recognized for the purpose of the Grad.Inst.P. regulations, since those elected to that grade automatically become Fellows of The Physical Society.".

Amendment 13: That paragraph 14 be deleted and the following be substituted therefor: "The Council will direct and manage the property and affairs of the Institute and Society, and the President will be responsible to the members for ensuring that its actions are in accordance with the Institute and Society's constitution and regulations."

Amendment 14: That in paragraph 15(*a*) the word "matters" be added after the word "professional".

Amendment 15: That the second sentence of paragraph 22 be deleted and the following substituted therefor: "Professional matters will be dealt with by a committee or committees consisting of Honorary Fellows of the Institute and Society and/or Fellows of The Institute of Physics and/or Associates of The Institute of Physics.".

Amendment 16: That at the end of paragraph 26 the following words be added: "No Fellow, Associate or Graduate of The Institute of Physics shall be required to pay an annual fee in respect of his Fellowship of The Physical Society additional to that due from him as such Fellow, Associate or Graduate."

Amendment 17: That at the end of paragraph 30(*c*) the following words be added: "and such other person or persons as the Council shall decide in respect of any particular meeting.".

The President announced that at an Extraordinary General Meeting of The Physical Society held on 27 November last an identical Resolution had been passed by an overwhelming majority.

Mr. F. W. G. Greener (*Associate*) moved the following amendment which was seconded by Mr. G. L'E. Turner (*Associate*) ; that in the proposed amendment 13 all the words after the word " therefor " be deleted and the following be substituted therefor:—

" The Council shall manage and direct the affairs of the amalgamated body, and shall be responsible to members therefor. The President shall supervise the conduct of affairs by the Council."

After discussion Mr. F. W. G. Greener's proposal was defeated on a vote (by a show of hands), by 29 votes to 4.

The President undertook to call the attention of the first Council of the amalgamated body to Mr. F. W. G. Greener's views and to invite them to consider them when examining the draft Articles of Association of the new body. The Special Resolution was then put to the vote and carried unanimously.

The President mentioned that had a poll been demanded, the Secretary held 1123 proxies and all but 14 of these instructed him to vote for the Special Resolution as circulated.

The President announced that Sir John Cockcroft (*Past President*) had agreed to serve as the first President of the amalgamated body and that other distinguished physicists, with the approval of the Board of the Institute and the Council of the Society, were being invited to fill the various honorary offices and to serve as members of the first Council. It was hoped that it would hold its first meeting early in the New Year when it would consider for adoption the draft Memorandum and Articles of Association and By-laws of the new company which had been prepared by the Joint Committee of the Institute and Society, which had worked out the scheme for amalgamation. If all goes well it is anticipated that the new body will come into official existence in the spring and that the old ones will be formally wound up in the summer of 1960 when their assets and liabilities will be handed over to the new body. The arrangements regarding the publications and individual members' subscriptions will remain unchanged in 1960 and changes, if any, which will become operative in 1961 will be announced as soon as they are determined by the new Council.

Payment of annual fees

Members are again asked to co-operate in reducing the cost and labour of collecting fees by using the form printed on page iv. This form is *not* intended for those members who pay fees by bankers' order.

Binding of the Bulletin

Members who wish to have their 1959 volume of the *Bulletin* bound are asked to send the twelve issues direct to the printers, F. J. Milner & Sons Ltd., Commerce Road, Brentford, Middlesex, as soon as possible, enclosing a sheet giving the name and address of the sender and a remittance made payable to the firm. The cost is twenty-three shillings a volume, including return postage. The binding is in red cloth with gold lettering on the front and spine.

The Teaching of Mathematics to Physicists

A completely new edition of the Institute's report *The Teaching of Mathematics to Physicists* is now available. In some respects it represents a different point of view from that expressed in the earlier version, originally published in 1944. The price to non-members is 2s. 6d. but members may obtain copies for their personal use, free of charge. Requests should be sent to the Deputy Secretary.

British United Provident Association : Group Scheme for Institute members

Members are reminded that the Board of the Institute has agreed to sponsor a Group Scheme of insurance with the British United Provident Association. This scheme, open only to Fellows, Associates and Graduates of the Institute and the permanent staff, ensures against the cost of nursing home fees, surgical operations and specialist treatment. The Association is a non-profit-making organization. A Group Scheme provides significant advantages, including a 20% reduction of the standard rates of subscription and the waiving of the normal waiting period of three months.

Members who would like to have details of the benefits and subscriptions may obtain them from the Secretary of the Institute.

Physical Society conferences

The Physical Society has arranged three conferences for the first half of 1960. These are on Classical and Quantum Turbulence (March 21 and 22 at Oxford), Nuclear Physics (Easter at Liverpool) and Diamond Physics (July at Reading).

Details and application forms may be obtained from the Secretary of the Society.

Reviews of Books

THE DEVIL'S REPERTOIRE

By Victor Gollancz

London: Victor Gollancz Ltd. Pp. 192. Price: Bound 10s. 6d., Paper 5s.

This book, subtitled "Nuclear Bombing and the Life of Man," is "the spiritual or religious case . . . in favour of unilateral nuclear disarmament." "Unilateral disarmament" is in some quarters almost a dirty phrase and the likelihood is that the book will be read only by the converted. Which is a pity.

The book can easily be read at one sitting. Following an introductory chapter, there are chapters on "Spirit and Matter," "Spirit and Ethics," "The Bomb" and "The Devil's Repertoire." "Spirit and Matter" endeavours to establish the reality of the spiritual world, and the supremacy of spiritual values, a task which has been done better elsewhere, and by scientists too. Anyone who had read, for example, Eddington's *Science and the Unseen World* or George Jeffery's *Christ Yesterday and To-day* (to mention only very short books) might find the present chapter somewhat superficial, but there may be some who will gain insight from it. One's first reaction may be to question whether the chapter is necessary, but then one remembers that there is perhaps a majority of British people to-day to whom the Bible and the great classics of religion are virtually unknown.

"Spirit and Ethics" is, in my opinion, the best part of the book. It is written with the same passion that characterized Gollancz's *Our Threatened Values*, that remarkable and courageous expression of liberalism which a decade ago caused countless people, myself included, to feel unbounded gratitude to its author.

On the chapter on "The Bomb" my only comment is that I found some passages with which I strongly disagreed, and others with which I wholeheartedly concurred. Most readers, I hope, would have a similar experience.

The last chapter deals with some of the standard objections to Gollancz's position—with such expressions as, "You can't apply Christianity to politics" and "You can't be soft with such people."

The book is written with passion but is transparently honest and makes no attempt to minimize the possible consequences of the policy that is advocated. What Gollancz does minimize, in my view, is the importance of the first Christian commandment as an essential prerequisite of compliance with the second. The superhuman courage needed to maintain ethical behaviour in circumstances such as Gollancz describes may be possible to men who love a personal God revealed to them as in the Christian faith, but I cannot conceive of such behaviour in those who merely love "the spirit."

NORMAN CLARKE.

PHYSICAL SCIENCE — A BASIC COURSE

By John C. Hogg, Judson B. Cross, Kenneth E. Vordenbert

London: D. Van Nostrand Co. Ltd. Pp. xi + 604. Price 37s. 6d.

PHYSICS — AN EXACT SCIENCE

By Harvey E. White

London: D. Van Nostrand Co. Ltd. Pp. xi + 597. Price 45s.

LABORATORY EXERCISES FOR PHYSICS

By Harvey E. White

London: D. Van Nostrand Co. Ltd. Pp. vii + 184. Price 22s. 6d.

The content of a school science course is being discussed by many science teachers and others. What is the science which the educated citizen should have when he leaves school? What, also, is the fundamental science with which the specialist should be equipped before he starts his university or other training? In other words, what should we teach for Ordinary and Advanced Level G.C.E.?

The problem is not confined to this country. Indeed all countries are experimenting with new ideas and new methods of presentation. There is too, a general shortage of good science teachers, but perhaps this particular difficulty is most acute in the U.S.A. where many aids to teaching are being developed, not the least being adequate textbooks. It is a little difficult to compare their textbooks with ours because they are written for different age groups. In general our boys and girls will have had at least five years of physics by the time they reach sixteen. In America, it seems usual for serious science to begin at sixteen or even later, thus an "elementary" textbook for use in America tends to be very full and to include much material which we would think unsuitable for beginners. On the other hand much of our traditional material is omitted, and it is this aspect which will help teachers in this country to prepare the ideal syllabus. There is no doubt that much of what we teach could very well be omitted with great benefit, and some of the more modern physics included.

There are several organizations in America which have studied these syllabus problems, and have made their reports. The magnitude of the task they set themselves is illustrated by the textbooks, apparatus, monographs, films, film strips which have been published, and even courses for teachers which have been arranged. The three books which are listed above are part of the "D. Van Nostrand Science Program," and concern mainly physics. Other books in the series cover biology, chemistry and what we might call general science.

The Preface to *Physical Science—A Basic course* illustrates the common problem. "To-day it is taken for granted that science must be part of the stock-in-trade of an educated person; it is generally agreed that science should form an essential part of the hard core of a school

curriculum. The only difference of opinion concerns the nature of the science courses." Thus the standard of the book is roughly what we would call Ordinary Level, but the content is very different from what we might expect. There are 10 " Units " or Sections, sub-divided into a total of 55 chapters. Topics considered include The Earth, Weather, Fuels, Electricity, Light, Communications, Atoms and Star, and there is an obvious attempt (with success) to show the interdependence of physics, chemistry, geology, meteorology and astronomy. At the end of each chapter are brief summaries, Things to Remember and Things to Do. There is a useful glossary and index.

The second book *Physics—An Exact Science* and its companion *Laboratory Exercises in Physics* are, presumably, the next step. It is described as " a high level introductory physics text in a high-school science program." An interesting comment in the Preface is " Where the allotted time schedule for physics does not permit the utilization of all the lessons, the author suggests the omission of the subjects Sound and/or Heat and strongly recommends the retention of Mechanics, Electricity and Magnetism, Atomic Physics, Electronics, Quantum Optics and Nuclear Physics." As this book is roughly equivalent to our Advanced Level, the subjects regarded as the more important, are, to say the least, interesting to our Sixth Form teachers.

The book is divided into 12 sections, and subdivided into lessons of which there are some 160. Each lesson ends with a summary and a list of questions designed to test " mastery and understanding," and problems to test " ability to apply the principles." Neither appear to really extend the student and the impression gained is that the intention is for the student to acquire knowledge rather than to encourage him to pose problems and carry out his own investigations to solve them. The lessons cover a very wide range, from very elementary topics to Bohr atoms and atomic accelerators. In general qualitative explanations are given and illustrated by excellent diagrams. Units ? Definitely mks (rationalized) in the electricity and magnetism chapters ; newtons, dynes and lb. wt. all appear in the mechanics chapters.

The *Laboratory Exercises for Physics* is described as a guide and manual for the students, but in this country we would be more likely to call it teacher's guide ! Not much is left to the student, full instructions, sample readings and what to do with them, only then is the student asked to show some initiative in answering some questions.

There are many good things in these books, in treatments which are new, ideas for demonstrations, and experiments which really do achieve their object. No doubt we would prefer more emphasis on a logical development in the theoretical work and more initiative in practical work on the part of the student. The books are certainly worth examining, but like so many American books have a high price. On the other hand the two major books are well bound and clearly printed. One would have expected the *Laboratory Exercises* to be equally well bound.

E. W. TAPPER.

MATHEMATICS IN PHYSICS AND ENGINEERING

By J. Irving and N. Mullineux

New York and London : Academic Press Inc. Pp. xvii + 883. Price 63s.

It is interesting to find the fifth volume in a series of monographs and textbooks on Pure and Applied Physics devoted to mathematics in physics and engineering. There is of course much from which to choose. The authors have selected the topics included in this attractive volume in the hope that the reader might be in " a position to understand the mathematics that appears in current technological journals." It is a gigantic task, which they have done well.

The equations of mathematical physics are not derived, which is a loss but understandable in view of the size of the book ; the emphasis is on methods of solution. The book opens with partial differential equations, and in keeping with a plan maintained throughout, deals with examples drawn from many branches of applied science. There follows chapters on the series method of Frobenius, Bessel and Legendre functions and spherical harmonics, and Laplace transforms. There is a useful introduction to matrices, and good chapters on complex variable theory, calculus of residues and conformal transformations.

One welcomes the inclusion of some work on numerical methods, restricted though it is, and the chapters on the calculus of variations and integral equations. Finally, there is an appendix of pure mathematics " to supplement the text." At the end of each chapter there is a useful set of examples.

One wonders for whom the book is intended. The authors suggest that much of the subject matter has been included in lecture courses at undergraduate and postgraduate levels. There is, however, much here that could not be included at the undergraduate stage, which only underlines the need for postgraduate courses.

The book is beautifully printed and bound, but too heavy to hold !

J. TOPPING.

HYDRODYNAMICS

By D. H. Wilson

London : Edward Arnold (Publishers) Ltd. Pp. viii + 149. Price 30s.

The stated object of this book is to provide, primarily for students specializing in mathematics and theoretical physics, a brief and concise introduction to " classical " hydrodynamics while at the same time providing the basis and acting as the starting point for the study of the many modern developments in fluid mechanics. All teachers have views as to how this should be done and my own I'm afraid do not coincide with the author's either in overall concept or detailed treatment. The book is I suspect too circumscribed for the potential specialist and too difficult in parts for the rest.

A more elementary treatment of viscosity based on pipe and channel flow would have been much more in place in a book of this type than the attempted generalities presented. As it is we find an analysis of stress based

on the ideas of Cartesian tensors, an analysis of rate-of-strain designed apparently to avoid the tensor concept and a " viscosity hypothesis " which leads the author to an equation of viscous compressible flow (eqn. 29) seriously at variance with the accepted one. (Equation 29 corresponds to a term 2μ grad div q in place of the usual $\frac{4}{3}\mu$ grad div q and this is no mere misprint.)

There are unfortunately other blemishes too—statements about the viscosity of air and water which would have been much better couched in terms of Reynolds number, definitions of Rayleigh number, vortex street and laminar flow which do not accord with 1959 accepted standards, a brief treatment of circulation around an aerofoil which suggests to me that the circulation grows indefinitely in steady flow, and a misleading sentence on page 5, lines 4-7.

Had this been a first draft one might have felt it had potentialities particularly in the neatness and conciseness of the treatment of parts of inviscid flow theory but in its present form it does not seem suitable to me for its purpose.

L. Howarth.

ANALYSIS OF LINEAR SYSTEMS

By D. K. Cheng

Massachusetts: Addison-Wesley Publishing Co. Inc., London: Pergamon Press Ltd. Pp. xiii + 431. Price 64s.

Although the title of this book is not very informative, it is undoubtedly appropriate as the book is essentially an account of the mathematical techniques necessary for the investigation of engineering systems. The author's primary intention seems to have been to enable the student to solve electrical circuit, transmission line and control system (including sampled-data system) problems. The book is therefore written in terms of electrical circuits but the approach is very general and appropriate to other branches of engineering also. Of particular interest in this connection is a chapter on electrical analogues of mechanical and electromechanical systems. In some sections the treatment is indeed rather too general and would have been greatly improved by the introduction of more specific examples in the text. This criticism applies particularly to the chapter on systems with feedback although even in the remainder of the book the emphasis is very obviously on analysis rather than on systems. There is, however, a really excellent collection of realistic problems at the end of each chapter.

After a chapter on classical methods of solving differential equations, there are chapters on electrical circuit theory, analogous systems and on analysis by Fourier methods—this latter particularly well done. The remainder of the book is concerned largely with the Laplace and $\mathcal{Z}$ transformations and their applications. Laplace transforms are introduced by way of the Fourier integral, a method which seems much more satisfactory than the more usual (in a book of this kind) empirical approach. In his preface the author expresses the opinion that students should not be led to believe that the Laplace transform method is always superior to other methods of solving linear differential equations. Despite this the book is dominated by the Laplace transform and classical methods are largely confined to the introductory chapter.

Undergraduates will probably find this book rather hard going for the treatment is thorough and reasonably rigorous. However, both graduate and undergraduate engineers or engineering-physicists will find time spent in mastering the techniques described in this book to be of great value.

A. E. De Barr.

GRUNDLAGEN UND ANWENDUNG DER RÖNTGEN-FEINSTRUKTUR-ANALYSE

By Hans Neff

Munich: R. Oldenbourg Verlag. Pp. 447. Price DM 73.

In his foreword the author suggests that most workers in the field of X-ray structure analysis discover that there are gaps in their knowledge and experience, either in the fundamentals of crystallography, in the theory of diffraction, or in the use of equipment. The aim of his book is to deepen understanding of fundamentals, to help with practical investigations, and to supply some knowledge of the way in which the structures of crystals depend on the binding forces in them. The book is addressed not only to chemists, physicists and technologists who are directly concerned with X-ray investigations, but also to readers with some background of physics who wish to gain some knowledge of the possibilities of the methods. It seems to be implicit in the author's attitude (as in that of others before him) that everything that is necessary for the successful application of X-ray crystallography can be put down in a book ; in my opinion no attempt to produce such a book can be wholly successful because X-ray structure analysis has still something of art as well as science in it, and can only be learnt satisfactorily through practical experience, preferably by apprenticeship. This is not to say that the apprentice can do without books, and the present one has much to commend it.

The book covers the physical principles of the generation and detection of X-rays, the principles of crystallography and of X-ray diffraction, the uses of powder cameras and counter diffractometers, the interpretation of powder photographs, the precision determination of lattice constants, and the application of powder methods for identification, analysis, and textural studies of various kinds. The last part (about 60 pages) gives a brief account of the principles of crystal chemistry and of the structures of various important groups of substances. It is very well produced, copiously illustrated, well written, and remarkably free from misprints.

Two general criticisms can be made of the book. Firstly, on many subjects it is not up-to-date (there are only eight references to original papers later than 1955, of which seven are German-language). Secondly, although the title of the book would lead one to expect it, there is very little information on single-crystal methods and the determination of crystal structures ; the book

is heavily biased towards powder methods and their technological applications. The numerous line drawings are good but in my opinion half-tone illustrations of apparatus are of doubtful value, more especially as in this case they are confined almost exclusively to the products of the company with which the author is associated.

Although the book is a useful introduction to the subject for German-reading beginners, especially if they are concerned with technological applications, there is little in it that English readers cannot get equally well or better from books in their own language.

E. G. Cox.

ELEKTRIZITÄTSLEHRE

By Heinz Schilt

Basel : Birkhauser Verlag. Pp. 216. Price sFr. 24.

This book presents clearly, competently and in a modern manner an elementary theory of electricity and magnetism. The avowed objective is an introductory course up to the generalization of the subject in Maxwell's equations. It deals with electric charges and fields, d.c., magnetic fields, a.c., oscillations and waves. The standard is suitable for the first years of a university course.

M. R. Gavin.

NON-DESTRUCTIVE TESTING

By J. F. Hinsley

London: Macdonald & Evans Ltd. Pp. xxxiv + 495. Price 75s.

Mr. Hinsley has provided us with a most useful addition to the limited number of books available on the subject of Non-Destructive Testing. Due no doubt to the author's background the contents are confined to the problems associated with the metal industries. However, many of the techniques discussed are of much wider application.

The general aspects of radiography, ultrasonic flaw detection and eddy current testing are well covered, particularly the latter which with the aid of first class illustrations make the subject easily understandable. It is a pity that more space is not devoted to techniques which are as yet not generally accepted. After all here is the starting point for further development work.

The mathematics necessary for following the theories of non-destructive testing are adequately dealt with. Sometimes, however, the author attempts to simplify a mathematical process at the expense of clarity. Reference to a textbook is recommended but Hardy's *Pure Mathematics* seems an unwise choice.

I can recommend without reservation the chapter on radiography to teachers of applied physics. The sections dealing with the essential requirements of a dark room and protection against radiation hazards are excellent. The book is written in a pleasing style making its contents easy to digest. It should not be omitted from the library of any organization employing the techniques of non-destructive testing.

P. Lord.

DIFFERENTIAL GEOMETRY

By Erwin Kreyszig

London : Oxford University Press. Pp. xiv + 352. Price 48s.

The subject of differential geometry is not an easy one, and he who would master it must be prepared for some hard slogging. This book, which is number 11 in the series Mathematical Expositions, provides an introduction to the differential geometry of curves and surfaces in three-dimensional Euclidean space. It is nevertheless a book for advanced students. An arc of a curve is a point set in space R_3 which can be represented by the allowable representations of an equivalence class.

The student with a background knowledge of calculus should not be put off however. The terms are explained, and the definition is only formulated after careful preparation of the ground. The reader will readily appreciate the need for such an apparently abstract definition. The subject matter is in fact presented in the simplest possible form consistent with mathematical rigour.

Full use is made of the tensor calculus which is developed as required, and the book might just as well be regarded as an introduction to tensor analysis.

Numerous very good line drawings are included, as well as many examples and problems. The answers to problems at the end of the book are in fact solutions. There is a useful collection of the more important formulae and results.

Altogether, this is an extremely good book, and the price is very reasonable for these days.

One small error was noticed in the statement of theorem 40.2, which states " At any elliptic or parabolic point P the surface S, considered in a sufficiently small neighbourhood of P, lies entirely on one side of the corresponding tangent plane." This may not be true for a parabolic point, for example at the origin on the surface $x_3 = x_2^4 - x_1^2$, or with possibly more familiar symbols $z = y^4 - x^2$.

A. W. Gillies.

News of Members

FELLOWS

N. F. Astbury is now Director of the British Ceramic Research Association, Stoke on Trent.

J. C. Bell has joined the staff of the Lucas Heights Research Establishment of the Australian Atomic Energy Commission.

Professor E. G. Cox has been appointed Secretary of the Agricultural Research Council as from July 1960.

A. Dinsdale has been appointed Deputy Director of Research of the British Ceramic Research Association, Stoke on Trent.

P. J. Duncton is now a Director of Fairey Aviation Ltd., Heston Division.

J. W. Illingworth has now taken an appointment in the Research and Development Department of Albert E. Reed & Co. Ltd., Maidstone.

Professor F. Llewellyn Jones has been awarded the V. C. Boys' Prize of The Physical Society.

Professor R. V. Jones has been awarded the Duddell Medal of The Physical Society.

Professor J. T. Randall and Dr. H. A. H. Boot (*Associate*) have jointly received the American John Scott Award for their invention of the cavity magnetron.

Sir George Thomson (*President*) is the new President of The British Association for the Advancement of Science.

D. Williams has been appointed Head Master of Duffryn High School, Newport, Monmouthshire.

ASSOCIATES

S. G. G. Aston is an Assistant Lecturer at the South-East Essex Technical College, Dagenham.

R. Brymner has been appointed Chief Design and Development Engineer of N.G.N. Electrical Ltd., Accrington.

G. E. Buckley is Chief Technical Manager at the Windscale and Calder Works of the U.K. Atomic Energy Authority.

G. W. G. Court has become Chief Engineer of Pye Proprietary Ltd., Melbourne, Australia.

J. O. Cutress is Senior Assistant Engineer (Physicist) in the Research and Development Department of the Central Electricity Board (South-Western District).

J. K. Easlea is Senior Lecturer in Physics at the City of Portsmouth Training College.

D. M. Evans has joined the Research and Development Branch of the U.K. Atomic Energy Authority, Windscale.

T. L. Goodfellow is a Lecturer in Physics at the Northampton College of Advanced Technology, London.

R. W. Hall has been appointed Lecturer in Physics at Sunderland Technical College.

F. Jackson is a physicist with the U.K. Atomic Energy Authority at Chapelcross Works.

W. James is a Lecturer in Physics at Birmingham College of Advanced Technology.

J. H. Leck has been promoted Senior Lecturer in the University of Liverpool.

P. A. Lee has been appointed Senior Lecturer at Brighton Technical College.

G. V. Marr is a physicist with the Atomic Power Division of the English Electric Co. Ltd., Leicester.

H. B. Mohanti is now a Senior Scientific Officer in the Defence Science Laboratory at New Delhi, India.

D. H. Morton has been appointed Physics Section Leader in the Research and Development Division of British Cellophane Ltd. at Bridgwater, Somerset.

B. O. Smith is now a Senior Development Engineer with Baldwin Industrial Controls Ltd., Dartford.

R. N. Stone has been appointed a Lecturer at Sunderland Technical College.

GRADUATES

P. Benjamin has been appointed Director in charge of Research and Development of James Dougall and Sons Ltd., Bonnybridge.

R. I. Brebner has joined the staff of Shell Chemicals Ltd., Carrington.

C. A. Burden is now Assistant Manager of Automatic Welding in the Development Department of Quasi-Arc Ltd., Gateshead.

J. W. Cole has been appointed Headmaster of Dewsbury Secondary Technical School.

M. E. Delany has been appointed to a Research Fellowship in the Department of the Education of the Deaf at the University of Manchester.

R. Dignum is now at the Department of Mathematics of the Royal Military College, Kingston, Ontario, Canada.

J. W. Dunn is a physicist with the English Electric Co. Ltd., Stafford.

N. T. Gallagher is Assistant Sales Manager of Shandon Scientific Co. Ltd., London.

S. S. Gould has joined the Research Department of Smiths Aircraft Instruments Ltd., Bishops Cleeve.

P. I. Johnson is now with Mullard Research Laboratories at Salfords.

D. R. Johnstone is with the Colonial Pesticides Research Unit, Porton Down.

L. A. Mackenzie is the Deputy Regional Physicist of the Eastern Regional Hospital Board, Dundee.

F. J. L. Makepeace is now at Batasfe Petroleum Indonesia Maatchappij, Pladju Refinery, Sumatra.

D. J. McNeill has joined the Plessey Co. Ltd., Caswell.

P. W. Matthews now holds a Research Post at the Clarendon Laboratory, Oxford.

D. Mills holds a Post-Doctorate Fellowship of the National Research Council of Canada.

F. V. Morgan is an Assistant Physics Master at Stonyhurst College, Whalley.

T. C. Poh is an engineer with G.E.C. (Malaya) Ltd.

I. T. Pye has been appointed a physicist in the Research Division of the Pulp and Paper Division of MacMillan and Bloedel, Port Alberni, British Columbia, Canada.

H. C. Roe has been appointed Senior Scientific Officer at the Dounreay Experimental Reactor Establishment of the U.K. Atomic Energy Authority, Thurso.

T. Skardhamar is a Reactor Physicist at the Institute for Atomenergie Research Establishment, Sillestrom, Norway.

B. Thomas is now on the staff of the Applied Physics Department of the Welsh College of Advanced Technology, Cardiff.

Forthcoming Institute Meetings

THE following is the list of Institute meetings so far arranged for the second half of the 1959-60 session. Members of all grades may attend any of the meetings, whether or not they belong to the Branch or Group concerned. Where it is indicated that tickets or application forms are necessary early application should be made.

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
Jan. 11	**London** The Institute's House	Professor J. G. Wilson, F.Inst.P. (*University of Leeds*)	**The problem of primary cosmic radiation**	6.00 p.m.	London and Home Counties
Jan. 14	**Liverpool** The University	Dr. E. Mendoza (*University of Manchester*)	**Electronic applications of super-conductivity**	7.00 p.m.	Liverpool and North Wales
Jan. 15	**Bristol** The University	Mr. A. J. Garratt, M.B.E., A.Inst.P. (*International Scientific Research Exhibitions Ltd., London*)	**Science on television**	7.00 p.m.	South-Western
Jan. 15	**Newport** College of Technology	Dr. J. W. Menter, F.Inst.P. (*Tube Investments Research Laboratories, Cambridge*)	**The microstructure of crystalline solids**	6.00 p.m.	South Wales
Jan. 18	**Manchester** The University	Dr. J. B. Birks, F.Inst.P. (*University of Manchester*)	**Recent developments in scintillation counting**	7.00 p.m.	Manchester and District
Jan. 19	**London** The Institute's House	Dr. D. Bohm (*University of Bristol*)	**Relation of individual and collective aspects in plasma behaviour**	5.30 p.m.	Electronics
Jan. 20	**London** The Institute's House	Mr. H. J. Dunster (*Health and Safety Branch, United Kingdom Atomic Energy Authority*)	**Health physics**	6.00 p.m.	Education
Jan. 22	**London** The Horse Shoe Hotel, Tottenham Court Road	Dr. C. A. Taylor, F.Inst.P. (*Manchester College of Science and Technology*)	Group dinner followed by a talk on **The physics of music**	6.30 p.m. for 7.00 p.m.	Non-Destructive Testing
Jan. 25	**Edinburgh** The University	Dr. D. H. Fender (*University of Reading*)	**Eye movements and colour vision**	7.15 p.m.	Scottish
Jan. 26	**Glasgow** The University	Dr. D. H. Fender (*University of Reading*)	**Eye movements and colour vision**	7.15 p.m.	Scottish
Jan. 28	**Birmingham** Joseph Lucas Group Research Laboratory	Professor D. A. Wright, F.Inst.P. (*University of Durham*)	Visit to laboratory followed by a lecture on **Thermoelectric refrigeration** The number for this visit is limited and further details and application forms will be sent to Midland Branch members.		Midland
Jan. 29	**Newcastle-upon-Tyne** King's College	Professor S. K. Runcorn, F.Inst.P. (*University of Durham*)	**Rock magnetism and continental drift**	6.15 p.m.	North-Eastern
Feb. 2	**Aberdeen** The University	Mr. R. M. Sillito, F.Inst.P. (*University of Edinburgh*)	**Light waves, radio waves and photons**	7.30 p.m.	Scottish
Feb. 3	**Dundee** Queen's College	Mr. R. M. Sillito, F.Inst.P. (*University of Edinburgh*)	**Light waves, radio waves and photons**	5.30 p.m.	Scottish
Feb. 3	**Leeds** The University	Dr. D. Ross Miller (*University of Cambridge*)	**Modern work on friction**	5.00 p.m.	Yorkshire

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
Feb. 9	**Newcastle-upon-Tyne** King's College	Mr. J. O. Isard, A.Inst.P. (*University of Sheffield*)	**The electrical properties of glass**	6.15 p.m.	North-Eastern jointly with the Institute of Glass Technology
Feb. 11	**Liverpool** The University	Dr. L. L. Green (*University of Liverpool*)	**Nuclear models**	7.00 p.m.	Liverpool and North Wales
Feb. 12	**London** The Institute's House	Dr. J. Ring (*University of Manchester*) Dr. H. A. Gebbie (*National Physical Laboratory, Teddington*)	**Interferometric spectroscopy**	2.30 p.m.	Applied Spectroscopy
Feb. 12	**Swansea** University College	Dr. H. T. Miles, Grad.Inst.P. (*Associated Electrical Industries Ltd.*)	**The physics of fully ionized gases**	5.15 p.m.	South Wales
Feb. 15	**Manchester** The University	Mr. J. G. Crowther	Branch Annual General Meeting followed by a lecture on **The history of science in Manchester**	6.30 p.m. 7.00 p.m.	Manchester and District
Feb. 16	**Birmingham** Exchange and Engineering Centre	Dr. J. W. Glen (*University of Birmingham*)	**Physics of glaciers**	6.30 p.m.	Midland
Feb. 17	**London** The Institute's House	Professor S. Tolansky, F.Inst.P., F.R.S. (*Royal Holloway College, Egham, Surrey*)	Branch Annual General Meeting followed by a lecture on **The microstructures of surfaces**	6.00 p.m.	London and Home Counties
Feb. 17	**Harmondsworth** The Road Research Laboratory	Mr. N. W. Lister (*Soils section*) Mr. J. J. Trott, A.Inst.P. (*Special problems section*)	Visit to the Road Research Laboratory, Harmondsworth, Middlesex. Two short papers will be presented followed by a tour of the laboratories.	2.00 p.m.	Stress Analysis
		The number for this visit is strictly limited and further details and application forms will be sent to the members of the Stress Analysis Group.			
Feb. 19	**Gloucester** Technical College	Dr. A. B. D. Cassie, C.B.E., F.Inst.P. (*Wool Industries Research Association, Leeds*)	**Physics of clothing**	7.00 p.m.	South-Western
Feb. 19	**London** The Institute's House	Dr. P. Schagen (*Mullard Research Laboratories*)	**Electroluminescent image intensifiers**	6.00 p.m.	Non-Destructive Testing
Feb. 23	**London** The Institute's House	Dr. W. M. Lomer (*Atomic Energy Research Establishment, Harwell*)	**Magnetic properties of alloys**	5.30 p.m.	Electronics
Feb. 24	**Dundee** Queen's College	Professor J. C. Gunn (*University of Glasgow*)	**Parity non-conservation**	5.30 p.m.	Scottish
Mar. 2	**London** Imperial College of Science and Technology		Visit to the Mathematical Machines Laboratory of Imperial College including a talk by Dr. J. R. Barker, A.Inst.P., on **The role of the laboratory in education**	5.00 p.m.	Education
Mar. 3	**Aberdeen** The University	Professor J. Rotblat, F.Inst.P. (*St. Bartholomew's Hospital, London*)	**Biological hazards of radiation**	7.30 p.m.	Scottish
Mar. 4	**Edinburgh** The University	Professor J. Rotblat, F.Inst.P. (*St. Bartholomew's Hospital, London*)	**Biological hazards of radiation**	7.15 p.m.	Scottish
Mar. 7	**Glasgow** The University	Professor J. Rotblat, F.Inst.P. (*St. Bartholomew's Hospital, London*)	**Biological hazards of radiation**	7.15 p.m.	Scottish
Mar. 10	**Liverpool** The University	Prof. G. D. Rochester, F.Inst.P., F.R.S. (*University of Durham*)	**Cosmic rays in outer space**	7.00 p.m.	Liverpool and North Wales

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
Mar. 11	**London** The Institute's House	Dr. R. Jones (*Road Research Laboratory, Harmondsworth*)	**Analysis of road constructions**	6.00 p.m.	Non-Destructive Testing
Mar. 15	**Newcastle-upon-Tyne** King's College	Professor D. A. Wright, F.Inst.P. (*University of Durham*)	**Applications of thermo-electricity**	6.15 p.m.	North-Eastern
Mar. 17	**London** The Institute's House	Professor F. P. Bowden, C.B.E., F.Inst.P., F.R.S.	**The friction and deformation of solids at very high speed**	6.00 p.m.	London and Home Counties
Mar. 18	**Bristol** The University	Mr. H. L. Green, F.Inst.P. (*Chemical Defence Experimental Establishment, Porton*)	**Smokes and mists**	7.00 p.m.	South-Western
Mar. 18	**Cardiff** University College	Professor C. F. Powell, F.R.S. (*University of Bristol*)	**The origin of cosmic radiation**	6.15 p.m.	South Wales
Mar. 21	**Manchester** The University	Dr. L. Essen, O.B.E. (*National Physical Laboratory, Teddington*)	**Astronomical and atomic time**	7.00 p.m.	Manchester and District
Mar. 21	**Edinburgh** The University	Dr. J. B. Birks, F.Inst.P. (*University of Manchester*)	**Recent developments in scintillation counting**	7.15 p.m.	Scottish
Mar. 22	**Glasgow** The University	Dr. J. B. Birks, F.Inst.P. (*University of Manchester*)	**Recent developments in scintillation counting**	7.15 p.m.	Scottish
Mar. 22	**London** The Institute's House	Mr. P. O. Hawkins (*Services Electronics Research Laboratory, Baldock*)	Group Annual General Meeting followed by a lecture on **Neutron sources**	5.30 p.m. 5.40 p.m.	Electronics
Mar. 23	**Sheffield** The University	Mr. F. I. G. Rawlins, F.Inst.P., F.R.S.E. (*The National Gallery, London*)	Branch Annual General Meeting followed by a lecture on **Physics and the fine arts**	5.00 p.m.	Yorkshire
Mar. 24	**Nuneaton**		Visit to Motor Industry Research Association, Lindley The number for this visit is limited and further details and application forms will be sent to Midland Branch members.		Midland
April 6 to 8	**Nottingham** The University		Conference on **Solid state microwave amplifiers** Registration is necessary. Full details may be obtained from the Secretary of the Institute.		Electronics jointly with Radio Spectroscopy
April 7	**Liverpool** The University	Mr. C. W. Oatley (*University of Cambridge*)	**New techniques in electron and x-ray microscopy**	7.00 p.m.	Liverpool and North Wales
April 8	**London** The Institute's House	Speakers to be arranged	**Source units for spectrochemical analysis**		Applied Spectroscopy
April 8	**London** The Institute's House	Mr. R. S. Sharpe, A.Inst.P. (*Atomic Energy Research Establishment, Harwell*)	**Nuclear fuel element inspection**	6.00 p.m.	Non-Destructive Testing
April 8 and 9	**Reading** The University		Group Annual General Meeting and Spring Conference on **The borders of X-ray analysis** Registration is necessary. Full details may be obtained from the Secretary of the Institute.		X-Ray Analysis
April 11 to 13	**Keele** University College of North Staffordshire		Annual Conference The papers will mainly be on stress and strain measurements on fibres (both polymers and glass) Registration is necessary. Full details may be obtained from the Secretary of the Institute.		Stress Analysis
April 12	**Leatherhead** The Electrical Research Association	Mr. C. G. Garton, F.Inst.P. (*Electrical Research Association, Leatherhead*)	Visit to the laboratories of the Association followed by a lecture on **Physics of insulation**	to be announced	London and Home Counties

Admission by ticket only on application to the Secretary of the Institute.
Further details and application forms will be sent to members of the Branch.

Date	*Place*	*Speaker*	*Title*	*Time*	*Branch or Group*
April 21	**Middlesborough** Cleveland Scientific and Technical Institute	Mr. H. A. Prime, A.M.I.E.E. (*Brush Electrical Engineering Co. Ltd.*)	**The Jodrell Bank telescope**	6.30 p.m.	North-Eastern jointly with the Society of Instrument Technology
April 21	**Birmingham** The University		Group Annual General Meeting	5.00 p.m.	Education
April 21 to April 22	**Birmingham** The University College of Technology	Principal speakers to be announced	Joint Symposium on **The training of the industrial physicist**		Education jointly with Midland
	Registration is necessary. Full details may be obtained from the Secretary of the Institute.				
April 22	**Birmingham** University Union		Branch Annual Dinner	7.00 p.m. for 7.30 p.m.	Midland
	Further details will be sent to Midland Branch members.				
April 29	**Aberystwyth** University College of Wales	Dr. R. Morgan (*Hammersmith Hospital, London*)	**Some aspects of ionizing radiation in medicine**	5.15 p.m.	South Wales
April	Full details will be sent to members of the Electron Microscopy Group		Conference on **Correlation of optical and electron microscopy**		Electron Microscopy jointly with Royal Microscopical Society
May 2 to 4	**London** Institution of Mechanical Engineers		Joint Conference with Société Française de Métallurgie. The general theme will be on the relationship between structure and physical properties of materials and will include recent advances in non-destructive testing techniques.		Non-Destructive Testing
	Registration is necessary. Full details may be obtained from the Secretary of the Institute.				
May 3	**London** Park Lane Hotel		**Institute Annual Dinner**	7.00 p.m. for 7.30 p.m.	
	Further details will be sent to all members.				
May 12	**Liverpool** The University	Dr. J. W. Glen (*University of Birmingham*)	Branch Annual General Meeting followed by a lecture on **The physics of glaciers**	7.00 p.m.	Liverpool and North Wales
May 18	**Leicester** Associated Electrical Industries Lamp and Lighting Co. Laboratories		Visit to A.E.I. Lamp and Lighting Co. Laboratories followed by a lecture on **Artificial light sources for colour matching and allied problems**		Midland
June 4	**Reading** The University		Visit to the Physics Department of the University of Reading followed by a river trip to Henley.		Education
	The number for this visit is limited and further details and application forms will be sent to members of the Education Group.				
June 25			Summer meeting: visit to the Clarendon Laboratory followed by a river trip.		London and Home Counties
	Further details will be sent to London and Home Counties Branch members.				
June			A summer meeting is to be arranged date and details to be announced		Applied Spectroscopy
July 1			Summer meeting: visit to Royal Radar Establishment, Malvern. Details to be announced later.		South-Western
July 5	**London** The Institute's House		Annual General Meeting	5.00 p.m.	
July 6			Summer meeting: visit to Calder Hall.		Manchester and District
	Full details and application forms will be sent to Manchester and District Branch members.				
July 13	**Derby**		Summer meeting and visit to Rolls-Royce Altitude Test Plant		Yorkshire
	The number for this visit is limited and further details and application forms will be sent to members of the Yorkshire Branch.				

Branch and Group Committees

The Committees of the Institute's Branches and Groups in Great Britain are at present constituted as follows:—

LIVERPOOL AND NORTH WALES BRANCH

Chairman: Mr. F. I. Hurley, F.Inst.P.

Hon. Secretary: Dr. M. G. Davies, A.Inst.P.

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Mr. W. R. Eadington, Grad.Inst.P.
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Dr. W. C. A. Hutchinson, A.Inst.P.
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Mr. G. N. Peel, F.Inst.P.
Dr. E. E. Schneider, F.Inst.P.

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Chairman: Dr. G. A. P. Wyllie, F.Inst.P.

Hon. Secretary: Dr. A. R. Boyle, A.Inst.P.

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Dr. W. G. Ferrier, A.Inst.P.
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Mr. T. R. Prentice, F.Inst.P.
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Dr. N. Thompson, F.Inst.P.
Dr. M. L. Wright, A.Inst.P.

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Hon. Secretary: Dr. M. McCaig, F.Inst.P.

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Mr. B. Bradley, A.Inst.P.
Dr. A. Cuhliffe, A.Inst.P.
Dr. G. M. Leak, F.Inst.P.
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Dr. R. S. Tebble, F.Inst.P.

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Dr. J. G. Rider, A.Inst.P.
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Dr. E. G. Stanford, A.Inst.P.
Dr. J. Thewlis, F.Inst.P.

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Dr. H. Fessler
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Mr. S. L. Harris
Mr. V. M. Hickson, A.Inst.P.
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Mr. W. H. Ray
Mr. C. Snell
Mr. B. Sugarman, F.Inst.P.

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Dr. E. Aruja, A.Inst.P.
Prof. Sir Lawrence Bragg, F.Inst.P., F.R.S.
Dr. R. W. Cahn, F.Inst.P.
Dr. D. E. C. Corbridge, A.Inst.P.
Dr. D. W. J. Cruickshank
Dr. R. L. Gordon, F.Inst.P.
Prof. H. Lipson, F.Inst.P., F.R.S.
Dr. H. D. Megaw, F.Inst.P.
Dr. P. G. Owston
Dr. B. M. Rimmer
Dr. J. C. Speakman
Dr. K. Robinson, A.Inst.P.
Dr. E. G. Steward, F.Inst.P.
Dr. J. Thewlis, F.Inst.P.

Group News

Non Destructive Testing Group: Summer Conferences

The first joint meeting with a foreign society was held in Paris in 1958, with the Société Française de Métallurgie. Although only about forty members of the Institute attended the meeting it was very successful.

Technical sessions were full of interest; the non-technical sessions were equally valuable. We had ample opportunity to meet many French people with similar interests to the Group and with whom we were able to discuss scientific and non-technical matters.

The Institute's members were so impressed with the hospitality of the Société Française that the delegates wanted to make some tangible indication of their appreciation and in fact contributed financially to the idea. Thus it was decided to present the Société Française with a silver rose bowl as a souvenir of our first joint meeting. It was presented by Mr. B. R. Byrne, the Chairman, at the banquet held in Paris during the Journées d'Automne on October 22. A second meeting, with the Société Française as the guests of the Group, is planned for May 1960, in London.

The 1959 Conference was held in splendid isolation at Armathwaite Hall, by Lake Bassenthwaite. Again about forty members and their ladies attended. The papers were mixed, varying from electron-magnetic resonance to megavoltage radiography. An outing to Calder Hall was included and proved equally interesting to members and their ladies. This may have been due to the attractive colour schemes and the aura of ultra-modernity associated with the reactors and generator plant. Dinners are a popular feature of scientific meetings; Dr. H. M. Finniston spoke at ours. Photographs, taken immediately before the dinner, can be obtained from Dr. P. Lord.

G. M. Leak.

The Register

ELECTIONS TO MEMBERSHIP

THE FOLLOWING ELECTIONS WERE MADE BY THE BOARD ON DECEMBER 1, 1959

An asterisk (*) indicates transfer from another grade

FELLOWS (5)

*Brown, Arthur Frederick, M.A., Ph.D., Senior Lecturer in Natural Philosophy, University of Edinburgh.

*Cahn, Robert Wolfgang, B.A., Ph.D., Reader in Physical Metallurgy, University of Birmingham.

*Goss, Alan Jerome, B.Sc., Ph.D., Section Chief, Semiconductors Metallurgy Section, Marconi Research Laboratories, Chelmsford, Essex.

*Heastie, Roy, B.Sc., Ph.D., Lecturer, Queen Mary College, London.

Keohane, Kevin William, B.Sc., Ph.D., Reader in Physics, Chelsea College of Science and Technology, London.

ASSOCIATES (41)

*Barr, Leslie Williamson, B.Sc., Ph.D., Post-Doctorate Research Fellow, National Research Council, Ottawa, Canada.

Cairns, David John, B.Sc., Ph.D., Assistant Lecturer, Norwood Technical College.

Carter, John Bright Richardson, B.Sc., Senior Lecturer, Brighton Technical College.

*Cooke, Iain, B.Sc., Ph.D., Assistant Professor, University of Manitoba, Canada.

Cooper, Samuel Rex, B.Sc., Scientific Officer, Royal Radar Establishment, Great Malvern, Worcs.

Davis, Herbert MacDonald, B.Sc., Principal Scientific Officer, U.K. Atomic Energy Authority, Woolwich, London.

*Duncumb, Peter, M.A., Ph.D., Research Physicist, Tube Investments Research Laboratories, Hinxton, Nr. Saffron Walden, Essex.

Fleck, William, B.Sc., Senior Development Engineer, Short Bros & Harland Ltd., Belfast.

Gale, Hubert John, M.A., Senior Scientific Officer, Atomic Energy Research Establishment, Harwell, Berks.

*Gibbs, Harry Gordon, B.Sc., Senior Research Officer, Joseph Lucas Group Research Laboratory, Marston Green, Birmingham.

*Hale, Kenneth Frank, B.Sc., Senior Scientific Officer, National Physical Laboratory, Teddington, Middlesex.

Hampton, Brian Frank, B.Sc., Ph.D., Scientist, Vickers Research Ltd., Ascot, Berks.

*Harker, Thomas Henry, B.Sc., Assistant Master, Cheadle Hulme School, Stockport, Cheshire.

*Henderson, John Fergus, B.Sc., Lecturer, Paisley Technical College,

Hitchcock, Anthony John Michael, B.A., Ph.D., Assistant Technical Manager, U.K. Atomic Energy Authority, Warrington, Lancs.

*Hogg, William Reid, B.Sc., Ph.D., Lecturer, University of Glasgow.

*Kelly, Brian Thomas, B.Sc., Scientific Officer, U.K. Atomic Energy Authority, Windscale Works, Sellafield, Cumberland.

King, Joseph William, M.Sc., Ph.D., Lecturer, Rhodes University, South Africa.

*Kirkhope, James, A.R.C.S.T., Senior Physicist, Rolls-Royce Ltd., Hillington, Glasgow.

*Kitchingman, William James, M.Sc., Lecturer in Metal Physics, Manchester College of Science and Technology.

Long, James Victor Percival, M.A., Ph.D., Senior Research Assistant, University of Cambridge.

*McClelland, Samuel Edward, B.Sc., Ph.D., Lecturer, Brighton Technical College.

Magarshack, John Martin, B.A., Scientific Officer, The British Cotton Industry Research Association, Shirley Institute, Didsbury, Manchester.

*Manley, David Michael John Picton, B.Sc., Ph.D., Senior Scientific Officer, Royal Aircraft Establishment, Farnborough, Hants.

Martin, Stanley, B.Sc., Physicist, British Scientific Instrument Research Association, Chislehurst, Kent.

Metson, Gilbert Harold, Ph.D., D.Sc., Deputy Chief Scientific Officer, Post Office Research Station, Dollis Hill, London.

Mitchell, James Gault, B.Sc., Research Scientist, Associated Electrical Industries Ltd., Research Laboratories, Aldermaston, Berks.

*Moulson, Anthony James, B.Sc., Ph.D., Senior Scientific Officer, British Ceramic Research Association, Stoke-on-Trent, Staffs.

Peacock, Thomas Edward, B.Sc., Ph.D., Research Assistant, University College, London.

Raffle, John Frederick, B.Sc., Ph.D., Senior Physicist, The Cementation Co. Ltd., Rickmansworth, Middlesex.

Rodgers, Alan Leopold, B.Sc., Ph.D., Lecturer, University of Manchester.

*Russam, Kenneth, B.Sc., Senior Scientific Officer, Road Research Laboratory, D.S.I.R., Harmondsworth, Middlesex.

Saxena, M. C., M.Sc., Research Fellow, Electronics Department, University of Southampton.

*Sturman, Hugh Gregory, M.A., Physicist, U.K. Atomic Energy Authority, Calder Works, Sellafield, Cumberland.

Tobin, Norman Reginald, B.Sc., Senior Physicist, British Rubber Producers Research Association, Welwyn Garden City, Herts.

*Trotman, Robert Edward, B.Sc., Senior Physicist, Westminster Hospital, London.

Viswanathan, Arunachala, D.Sc., Senior Scientific Officer, Central Electro - Chemical Research Institute, Madras, India.

*Warren, Stanley Edward, B.Sc., Scientific Officer, U.K. Atomic Energy Authority, Springfield Works, Preston, Lancs.

*White, Maurice William, M.Sc., Assistant Lecturer, Coventry Technical College.

Wilkins, Ronald Towrass, B.Sc., Head of Department of Building and Engineering, Brooklyn Technical College, Birmingham.

Woods, Kenneth Brian, B.Sc., Lecturer in Electronics, Royal Air Force Technical College, Debden, Essex.

GRADUATES (56)

*Allen, Keith David, B.Sc., Graduate Apprentice, The English Electric Valve Co., Ltd., Chemlsford, Essex.

Andrew, David, B.Sc., Physics Master, Clitheroe Royal Grammar School for Boys, Lancs.

Aspinal, David Trevor, B.Sc., Research Engineer, Motor Industry Research Association, Nuneaton, Warwicks.

Baxter, Colin Benjamin, B.Sc., Research Student, University of Sheffield.

Bernstein, David Maurice, B.Sc., Junior Physicist, Plessey Nucleonics Ltd.

*Booth, Roy Sims, B.Sc., Graduate Apprentice Electrical Engineer, Metropolitan-Vickers Electric Co. Ltd., Trafford Park, Manchester.

*Bradbury, Phillip, B.Sc., Physicist, Nuclear Power Plant Co., Knutsford, Cheshire.

Butteridge, John Marcus, B.A., Scientific Officer, U.K. Atomic Energy Authority, Windscale Works, Cumberland.

Cassidy, Bernard Francis Desmond, B.Sc., Graduate Apprentice Electrical Engineer, Standard Telephones & Cables Ltd., London.

*Chinn, Gavid John, Graduate Apprentice, The Plessey Co. Ltd., Swindon, Wilts.

Clark, Bruce John, B.Sc., Junior Engineer, English Electric Aviation Ltd., Stevenage, Herts.

Darlow, Stewart Francis, B.A., Assistant Lecturer Manchester College of Science and Technology.

*Davies, Anthony James, B.Sc., Demonstrator, University College of Swansea.

*Davies, John, B.Sc., Assistant Engineer, De Havilland Propellers Ltd., Stevenage, Herts.

Day, Bryan Philip, B.Sc., Scientific Officer, Royal Aircraft Establishment, Farnborough, Hants.

Edwards, Geoffrey Philip, B.Sc., Electronic Engineer, Mullard Research Laboratories, Salfords, Surrey.

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*Fenn, Ruth Helen, B.Sc., Research Student, Davy Faraday Laboratory of the Royal Institution.

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Hargrave, Peter Hugh, B.Sc., Research Student, University College, London.

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Henderson, William Thomas Kinloch, B.Sc., Scientific Officer, Ministry of Supply, Royal Aircraft Establishment, Farnborough, Hants.

Hart, David Alfred, B.Sc., Assistant Master, Wyggeston Boys' School, Leicester.

Hughes, Nicholas David Peter, B.A., Assistant Experimental Officer, Royal Aircraft Establishment, Farnborough, Hants.

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*Larkham, Eric John, B.Sc., Technical Assistant, U.K. Atomic Energy Authority, Calder Works, Sellafield, Cumberland.

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Palmer, Rex Alfred, B.Sc., Research Student, Birkbeck College, London.

*Price, Colin Douglas, B.Sc., Research Student, University College of North Wales, Bangor.

Read, Tony Brian, B.A., Experimental Physicist, British Thomson-Houston Co. Ltd., Rugby.

Regan, David, M.Sc., Lecturer, Luton College of Technology, Beds.

Rice, Christopher George, B.Sc., Graduate Apprentice, Siemen Edison Swan Ltd., London.

Rodda, George William, B.Sc., Teacher, Claremont Bilateral School, City of Nottingham Education Committee.

Round, Peter Bernard, B.Sc., Process Development Physicist, George Bassett & Co. Ltd., Sheffield.

Scourfield, Malcolm William John. B.A., Head of Physics Department, John Port School, Etwall, Derby.

Shaw, Anthony Bernard, B.Sc., Research Student, University of Liverpool.

*Shields, Eric, Assistant Technical Officer, Imperial Chemical Industries Ltd., Billingham, Durham.

Shields, Patricia Kathleen, B.Sc., Assistant Information Officer, Tube Investments (Group Services) Ltd., Aston, Birmingham.

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Taylor, Michael Alan, B.A., Research Student, Cavendish Laboratory, Cambridge.
*Thomas, Richard Vincent, B.Sc., Graduate Trainee, British Thomson-Houston Co. Ltd.
Turner, Peter Charles Richard, B.Sc., Physicist, Radiotherapeutic Research Unit, Hammersmith Hospital, London.
Weatherhead, Rennie, B.Sc., Assistant Teacher, Peebles Burgh and County High School, Scotland.
*Williams, Aled Wyn, B.Sc., Ph.D., Theoretical Physicist, English Electric Co. Ltd., Whetstone, Leicester.
Williams, John Bryan, B.Sc., Physicist, Plessey Nucleonics, Northampton.
*Wrigley, Robert, Laboratory Technician, Mullard Blackburn Works, Ltd., Magnetic Components, Southport, Lancs.

Seventy-nine Students and two Subscribers were also admitted.

The Institute's Journals

PRINCIPAL CONTENTS OF THE JANUARY, 1960, ISSUES

Journal of Scientific Instruments : Volume 37, No. 1

Parametric amplification. By K. W. H. Stevens.

The purpose of this paper (which is based on a lecture given to the Electronics Group of The Institute of Physics) is to review the underlying ideas of parametric amplification. The discussion is mainly in physical terms and passes from simple circuit amplifiers to the more complex Suhl-types of amplifier. Mention is made of some of the directions in which research is proceeding.

Design and performance of a rapid-scanning X-ray diffractometer. By A. Skertchly, A.Inst.P.

The apparatus described enables the equatorial X-ray diffraction intensity distribution from radially symmetrical specimens to be obtained over the angle range 0 to 20° of Bragg θ in twenty seconds. Sequential scans are performed at the rate of two per minute and the X-ray intelligence is retained in the form of pulses by being recorded on magnetic tape when preserves the record with a high degree of fidelity. Also incorporated is an intensity analyser which enables the integrated count to be obtained between any two preset positions of Bragg θ, the limits being adjustable in steps of 0·1° to a high degree of precision. Although the instrument is designed primarily for the investigation of reaction kinetics in certain high polymeric substances of interest to the textile industry, there is obvious scope in other applications which involve relatively rapid changes in lattice perameters. Design details and some performance data are briefly mentioned together with an illustrative application.

Two thermocouples suitable for measurement of temperatures up to 2800°C. By D. A. Davies, A.Inst.P.

The thermoelectric characteristics of two high-temperature thermocouples of tungsten/26% rhenium-tungsten and tantalum/26% rhenium-tungsten are described, and a method of determining the e.m.f. of the couples up to a temperature of 2800°C is given. In the temperature range 1000-2000°C, the sensitivity of the tungsten/rhenium-tungsten couple is 16·2μV/°C. and that of the tantalum/rhenium-tungsten couple is 13·6μV/°C. The important feature of these thermocouples is their suitability for operation at much higher temperatures than existing couples, combined with a fairly high sensitivity.

Design of laboratory furnaces. By P. L. Start and M. W. Thring, F.Inst.P.

The paper illustrates the use of a heat balance in the design of small furnaces, and then discusses the principles of arc, arc-image, induction, electron-bombardment, resistor-heated and gas-fired furnaces. Constructional details are mentioned briefly with each type of furnace considered. A comprehensive table of resistor elements, refractory tubes and insulating materials and their properties is included. Methods of controlling small furnaces are discussed in the final section.

Apparatus for the measurement of the mechanical properties of fibres. By F. R. Morgan, A.Inst.P.

Apparatus for determining the mechanical properties of eight fibres simultaneously is described. The apparatus provides for tests to be made at different relative humidities, chainomatic loading up to about 450 g, and measurement of extensions of the order of 10^{-3} cm.

Recording weight meter. By D. J. Steele.

Modifications to a commercial platform weighing machine, to provide a continuous record of changes in weight of a standing load on the platform are described. With this instrument, weight changes of up to 55 lb in a maximum load of 560 lb can be recorded to an accuracy of 0·5%, i.e. less than 5 oz, which is the accuracy of the weighing machine itself.

An earlier instrument, although satisfactory for short periods of operation, was found to be unsatisfactory for measuring weight changes over a time in excess of a few hours, owing to random changes of up to 2 lb in full-scale calibration of 50 lb. This difficulty has been overcome in the present instrument by using photoelectric cells to detect the vertical movement of the steelyard, and a servo-operated mechanism to control the restoring force. The output, which is directly proportional to the change in weight on the platform, is in a form which is suitable for being recorded on a potentiometric recorder. It is substantially independent of normal ambient temperature changes; the calibration changes by 0·01% per °F change of ambient temperature. This error can be allowed for if the ambient temperature changes are known.

An electronic fluxmeter. By R. R. Birss, A.Inst.P., and J. P. Fry.

An instrument is described which possesses a number of advantages over a conventional fluxmeter. It has four operating ranges and may be used with a search coil of high resistance. Provision is made for self-calibration of both the sensitivity and the linearity of the instrument. The fluxmeter is suitable for operation by a non-scientist.

Densitometer wedge for measurements at low optical densities. By N. R. Silvester.

For the quantitative evaluation of electron micrographs a continuous wedge has been simply made in which, over the range 0 to 1·0 the optical density varies exponentially along its length within an accuracy of ±5%. Its construction and method of use are described. An application is indicated in measurements of the mass of electron-microscope specimens and similar uses in contact microradiography and microspectrophotometry are suggested.

British Journal of Applied Physics: Volume 11 No. 1

CONFERENCE REPORT

Summarized proceedings of a conference on electron microscopy—Exeter, July 1959.

The annual conference of the Electron Microscopy Group of The Institute of Physics was held in the Washington, Singer Laboratory, University of Exeter, from July 7 to 10, 1959. The papers presented are summarized in this report.

Size distribution of airborne dust samples from British coalmines. By J. W. J. Fay and J. R. Ashford.

This paper is concerned with the size-distribution analysis of samples of airborne dust from British coalmines, taken with the thermal precipitator and evaluated using the optical microscope. It is shown that many of the particles of less than 1μ in diameter present underground are probably associated with atmospheric pollution, and do not arise directly from mining operations. Consideration is then given to the size distribution of the above-1μ component of the dust. The results recorded on special samples by the Pneumoconiosis Field Research Unit, together with some published size-analyses of airborne dust in British and South African mines, are examined, and it is shown that a single-component exponential distribution provides a reasonably good fit to the observed data. The size distributions reported during routine sampling work at the 26 collieries associated with the Research are then analysed in terms of the exponential distribution. It appears that within any given colliery there is no considerable variation in size distribution between face-work on the coal-getting and preparation shifts and non-facework underground, although there is a suggestion that the airborne dust encountered in hard headings may contain a higher proportion of smaller particles than in other parts of the same colliery. There are, however, marked variations from coalfield to coalfield, the coarsest dust being reported in South Wales and the finest in Scotland. The implications of these results are discussed and it is shown that the 1-5μ particle number count is a satisfactory parameter for the measurement of the hazard associated with airborne dust.

Some statistical aspects of dust counting. By J. R. Ashford.

This paper is concerned with the application of statistical methods to the problem of evaluating samples of air-borne dust obtained with the thermal precipitator. A brief description is given of the nature of the dust sample, followed by an outline of the techniques employed to estimate the number of particles deposited. The three main sources of counting variation—systematic differences between observers, basic counting error and random distribution of particles in the dust deposit—are then considered. The effect of size distribution on counting errors is examined and it is shown that this factor may lead to appreciable variation in the recorded counts. Following a short description of various properties of the dust deposit which, although not strictly associated with the counting process, have a bearing on the reported concentration, recommendations are made about optimum procedures for counting thermal-precipitator samples.

Temperatures, thermal stresses and displacements in solid uranium dioxide rods. By J. P. Ellington.

Expressions are derived for the temperatures, stresses and displacements in a solid uranium dioxide fuel rod, the thermal conductivity of which decreases exponentially with temperature. Graphs of the temperatures and displacements are given, and calculation shows that the rod will fracture when the centre-to-surface temperature drop exceeds 80-90°C.

Sensitive method for measurement of magneto-resistance effect with direct currents and with microwaves. By D. E. Clark, A.Inst.P., and J. G. Assenheim.

An experimental investigation is made of the magneto-resistance effect in bismuth at frequencies of $9{\cdot}2 \times 10^9$, $1{\cdot}5 \times 10^9$ and $1{\cdot}1 \times 10^9$ c/s, in magnetic fields of intensities up to 6270 oersteds. Some results were also obtained using direct current. The method developed for the measurements is one of high sensitivity. In general form the results are in agreement with the theoretical predictions of Donovan.

Change of size of air bubbles in water containing a small dissolved air content. By D. M. J. P. Manley, A.Inst.P.

The rates of growth and collapse of air bubbles in distilled degassed water are studied. Experimental results show that the effective diffusion coefficient for air through the bubble walls is low at very small bubble diameters. These results are interpreted by the organic skin effect, and the physical qualities of this skin surrounding the bubble walls are discussed.

Variation with particle size of the effective X-ray absorption coefficient of heterogeneous slabs. By G. B. Mitra and A. J. C. Wilson, F.Inst.P.

The effective absorption coefficient for transmission of X-rays through heterogeneous slabs differs from the weighted-mean absorption coefficient because of random fluctuations in the number of particles of each type of material along different parallel paths. The value of μ_{eff} is calculated for several models; for each it is less than $<\mu>$, the difference becoming large for large particles.

Rotational hysteresis loss in grain-oriented silicon-iron. By W. F. Archenhold, H. Sandham and J. E. Thompson.

An improved torque magnetometer has been used to measure accurately the rotational hysteresis loss in grain-oriented silicon-iron for various percentage orientations and thicknesses. The experimental results are discussed in terms of multi-domain concepts and of the Stoner-Wohlfarth single-domain particle, of which the rotational-hysteresis behaviour has been evaluated. The possible relevance of this theory and its extensions to the experimental results are considered.

Measurement of tinplate thickness using fluorescent X-rays excited by a radioactive source. By J. F. Cameron and J. R. Rhodes.

Using tritium bremsstrahlung as an X-ray source and a thin-windowed scintillation counter as a detector, a method of measuring the thickness of tinplated steel over the range 0–1·55 microns (1·00 lb per basis box) has been developed. The technique depends on absorption of the iron fluorescent X-radiation by the tin layer. An accuracy of 1% can be obtained with 95% confidence in a counting time of 30 seconds.

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CONTEMPORARY PHYSICS

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